UNITED STATES
AMLR ANTARCTIC MARINE LIVING RESOURCES PROGRAM

AMLR 1992/93 FIELD SEASON REPORT

Objectives, Accomplishments and Tentative Conclusions

Edited by
Jane Rosenberg

MAY 1993

ADMINISTRATIVE REPORT LJ-93-08

Southwest Fisheries Science Center
Antarctic Ecosystem Research Group

The U.S. Antarctic Marine Living Resources (AMLR) program provides information needed to formulate U.S. policy on the conservation and international management of resources living in the oceans surrounding Antarctica. The program advises the U.S. delegation to the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), part of the Antarctic treaty system. The U.S. AMLR program is managed by the Antarctic Ecosystem Research Group located at the Southwest Fisheries Science Center in La Jolla.

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TABLE OF CONTENTS

BACKGROUND

The long-term objective of the U.S. Antarctic Marine Living Resources (AMLR) field research program is to describe the functional relationships between krill, their environment, and their predators. The field program is based on two working hypotheses: (1) krill predators respond to changes in the availability of their food; and (2) the distribution of krill is affected by both physical and biological aspects of their habitat. In order to refine these hypotheses, a study area was established in the vicinity of Elephant Island (Figure 1). A seasonal field camp was established at Seal Island, off the northwest coast of Elephant Island, where reproductive success and feeding ecology of seal and penguin breeding colonies are monitored. A complementary series of shipboard observations was initiated to describe both within and between season variations in the distributions of nekton, zooplankton, phytoplankton, and water types. In addition, research on the ecology of Adelie penguins is conducted at Palmer Station each year during the austral summer.

SUMMARY OF 1993 RESULTS

Six surveys were conducted between mid-January and mid-March, 1993. As in past seasons, two major water types were easily identified (Drake Passage and Bransfield Strait). Current flow was generally from southwest to northeast across the AMLR study area, with meanders seen northeast of Elephant Island. Similar to last year, phytoplankton biomass, as measured by chlorophyll-a concentrations, decreased markedly from Leg I to Leg II. Preliminary analysis of net plankton samples during Leg I showed a predominance of diatoms in all stations. Early in the season, krill were most abundant northwest of Elephant Island, between Elephant and Clarence Islands, and to the west between Elephant and King George Islands. Krill densities found during Leg II's large-area survey were low compared to that of Leg I, although comparable to a similar survey conducted at the same time last year. The overall krill length frequency distributions and maturity stage composition from this year's large-area surveys differed considerably compared to last year. In particular, a distinct juvenile mode was absent, suggesting poor spawning and/or larval survival from the 1991/92 season. Also, a relatively abundant intermediate size mode (around 35mm) suggests the apparent success of the 1990/91 krill year class. Salps were the overall dominant component of zooplankton samples collected. This season was a very good year for recruitment of chinstrap penguins, with increased numbers of birds attempting to breed on Seal Island. Despite this, only 72% of eggs present upon the field team's arrival hatched. In contrast, breeding success for chinstraps (chicks surviving to creche) was high at 92%. Total survivorship was comparable to past seasons at 67%, except for the 1990/91 season which was 59%. Breeding success of macaroni penguins was the highest recorded compared to all past seasons. Fur seal pup production on the island was very similar to last season. At Palmer Station, Adelie penguins enjoyed high breeding success this season, although not significantly higher relative to last year (1.46 vs 1.39 chicks creched/pair).

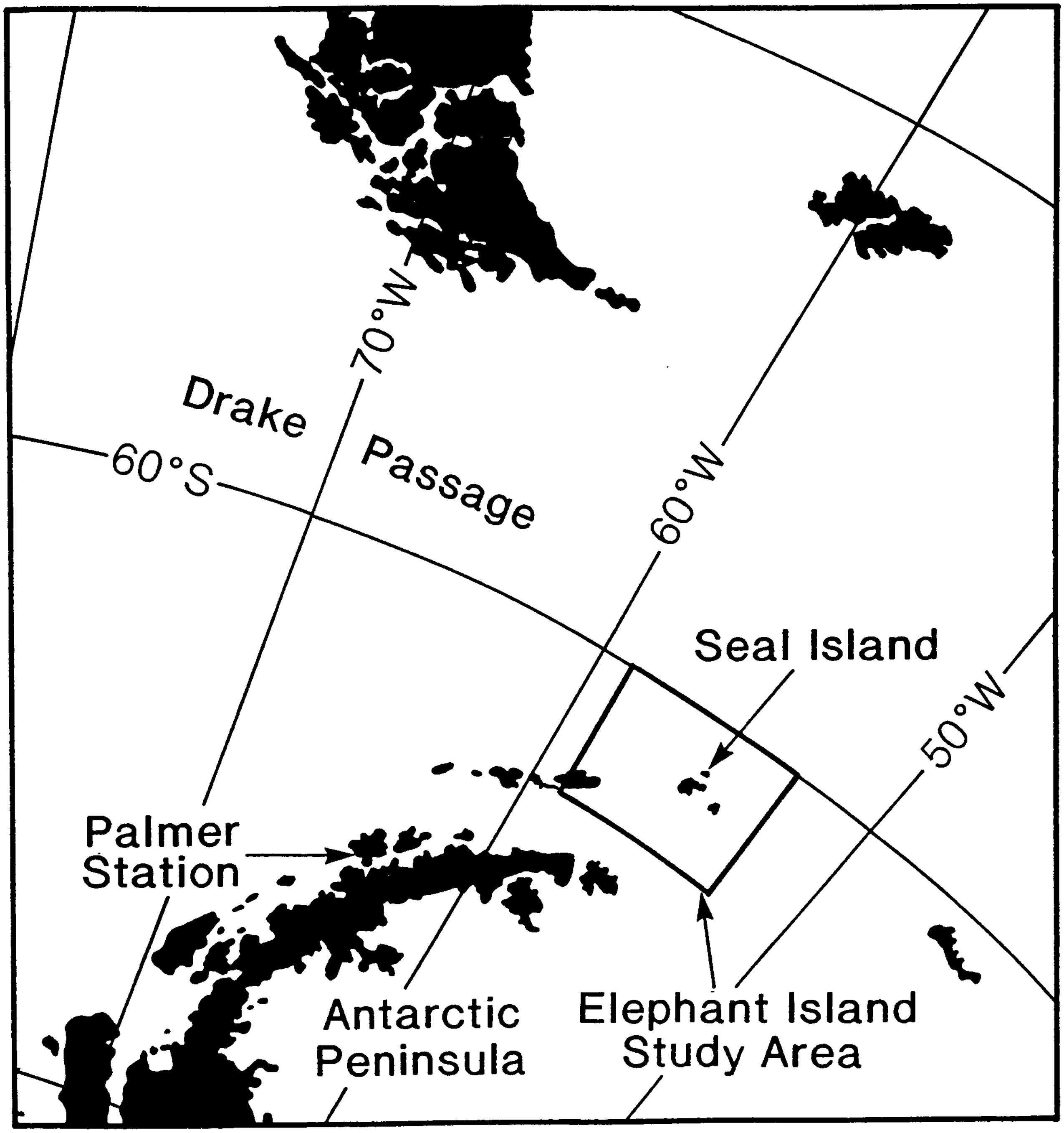

Figure 1. Locations of the U.S. AMLR field research program: Elephant Island Study Area, Seal Island, and Palmer Station.

OBJECTIVES

Shipboard Research:

1. Map meso-scale (10's to 100's of kilometers) features of water mass structure, phytoplankton biomass and productivity, and zooplankton constituents (including krill) in the area around Elephant Island.

2. Estimate the abundance of krill in the area around Elephant Island.

3. Delineate the hydrographic and biological features across the expected front north of Elephant Island.

4. Map the micro-scale (1-10's of kilometers) features of the distribution, density, and abundance of krill immediately north of Elephant Island, within the foraging range of krill predators breeding at Seal Island.

5. Provide logistic support to the Seal Island field camp.

6. Conduct pelagic seabird and marine mammal observations along the Central and South American coast during the Southbound transit, as well as in the AMLR study area during Legs I and II.

7. Conduct observations of seabird foraging patterns in relation to prey distribution in the AMLR study area during Legs I and II.

8. Determine effects of diel changes of krill behavior and orientation of survey transects on the description of krill distribution patterns.

9. Measure acoustic target strength of krill as a function of animal size, gender, and sexual maturity.

10. Investigate acoustic signatures of selected zooplankton species using multi-frequency technology and directed MOCNESS sampling.

Land-based Research:

<u>Seal Island</u>

1. Monitor pup growth rates and adult female foraging of antarctic fur seals according to CCAMLR Ecosystem Monitoring Program (CEMP) protocols.

2. Conduct directed research on pup production, female foraging behavior, diet, abundance, survival, and recruitment of fur seals.

3. Monitor the abundance of all other pinniped species ashore.

4. Evaluate an automatic direction-finding system for determining the offshore foraging areas of fur seals.

5. Monitor the breeding success, fledgling size, reproductive chronology, foraging behavior, diet, abundance, survival, and recruitment of chinstrap and macaroni penguins according to CEMP protocols.

6. Examine penguin chick growth and condition for intra- and inter-seasonal comparisons.

7. Conduct directed research on seasonal and diel patterns in the diving behavior of chinstrap penguins in order to assess changes in foraging patterns and effort as physical and biological components change through the breeding season.

8. Examine intra-seasonal changes in penguin chick provisioning contemporaneously with foraging effort.

9. Test an automatic direction-finding system for monitoring the locations of offshore foraging areas of chinstrap penguins.

10. Assess the reproductive success, survival, and recruitment of cape petrels.

Palmer Station:

1. Determine Adelie penguin breeding success.

2. Examine how present and past indices of Adelie penguin breeding success relate to a true measure of breeding success.

3. Obtain information on Adelie penguin diet composition and meal size.

4. Determine Adelie penguin chick weights at fledging.

5. Determine the amount of time breeding adult Adelie penguins need to procure food for their chicks.

6. Band a representative sample (1000 chicks) of the Adelie penguin chick population for future demographic studies.

7. Determine adult Adelie penguin breeding chronology.

8. Continue exploring the feasibility of adding more of the Standard Methods to the suite of data now be collected at Palmer Station.

DESCRIPTION OF OPERATIONS

Shipboard Research:

Itinerary

Southbound Transit:	Depart Seattle	4 December 1992
	Port call San Diego	9 December
	Port call at Valparaiso, Chile	31 Dec - 2 Jan 1993
	Port call at Punta Arenas, Chile	8 - 10 January
Leg I:	Depart Punta Arenas	11 January
	Re-provision Seal Island	14 January
	Survey A (first part)	15 - 19 January
	Cross-shelf transect	20 January
	Call at Seal Island	21 January
	Survey A (second part)	21 - 31 January
	Survey B	1 - 3 February
	Call at Seal Island	5 February
	Survey C (partial)	4 - 6 February
	Arrive Punta Arenas	9 February
Leg II:	Depart Punta Arenas, Chile	14 February
	Re-provision Seal Island	17 February
	ADF calibration transects	18 February
	Survey D	19 - 21 February
	Survey E	22 Feb - 6 March
	Bransfield Strait transect	7 March
	Cross-shelf transects	8 March
	Survey F	9 - 12 March
	Recover Seal Island team	10 March
	Inspect Polish F/V *Lyra*	11 March
	Arrive Punta Arenas	15 March

Southbound Transit.

1. Continuous underway measurements included ship's position, true wind speed and direction, air temperature, relative humidity, barometric pressure, solar radiation, sea surface water temperature, salinity, light beam transmission, and fluorescence.

2. Observations of birds and marine mammals were conducted.

Leg I.

1. The *Surveyor* took her departure from South America via the eastern end of the Strait of Magellan. Land fall was made at Seal Island, and most of the provisions were brought ashore to the AMLR field camp before rough seas required termination of small boat operations.

2. A large-area survey of 91 Conductivity-Temperature-Depth (CTD)/rosette and net sampling stations, separated by acoustic transects, (Survey A, Stations A1-A91, Figure 2) was conducted. Acoustic transects were conducted at 10 knots, using 120kHz and 200kHz transducers mounted in a towed body. Operations at each station included (a) measurement of temperature, salinity, oxygen, light, transmissometer, and fluorescence profiles; (b) collection of discrete water samples at standard depths for analysis of chlorophyll-a content, absorption spectra, particulate organic carbon and nitrogen concentrations, primary production, ATP and DNA content, size fractionation, floristics, and inorganic nutrient content; and (c) deployment of a large plankton net to obtain samples of zooplankton and nekton.

3. The towed body, housing the acoustic transducers, was lost approximately one-third of the way through Survey A. A cross-shelf series of CTD/rosette stations (Stations X1-X5, Figure 3) was conducted, and the remaining provisions for the Seal Island field camp were taken ashore, while a back-up towed body/acoustic transducer system was fabricated. Survey A was then completed using only one acoustic frequency and at a slower vessel speed.

4. A small-area acoustic survey was conducted north of Elephant Island (Survey B, Figure 4). The survey was conducted at a ship's speed of approximately 5 knots, 24 hours per day over a 3-day period with no CTD/rosette or net sampling stations.

5. Approximately one-half of the small-area acoustic tracklines was again surveyed during daylight operations (Survey C, Figure 4). During night time, MOCNESS sampling was conducted in areas of high krill density. The sampling effort was directed by simultaneous acoustic observations.

6. Continuous underway measurements were similar to those recorded during the Southbound transit.

7. Observations of the distribution and behavior of birds and marine mammals were conducted.

Leg II.

1. The *Surveyor* transited the same route as Leg I from Punta Arenas to Seal Island. A series of XBTs was conducted while in transit across Drake Passage by personnel from Chile's Servicio Hydrográfico y Oceanográfico de la Armada (SHOA). Fresh provisions and mail were transferred to the field camp at Seal Island.

2. A series of acoustic transects was conducted immediately north of Seal Island while towing a radio transmitter. The transmitter was similar to that used to instrument penguins during foraging trips; the data collected will be used to interpret observations made with an automatic frequency scanning receiver on Seal Island.

3. A small-area acoustic survey (Survey D, Figure 4) was conducted north of Elephant Island. The survey was conducted at a ship's speed of approximately 10 knots, 17 hours per day over a 3-day period. Directed IKMT and MOCNESS tows were conducted during the dark hours.

4. A large-area survey (Survey E, Stations E1-E91, Figure 2), similar to Survey A, was completed around Elephant, Clarence and Gibbs Islands. Acoustic transects were conducted at 10 knots using 120kHz and 200kHz transducers.

5. A transect with CTD/rosette stations (Stations X6-X12, Figure 5) was conducted across Bransfield Strait south of King George Island. Macro-nekton samples were obtained with an IKMT at the southernmost two stations.

6. Two transects with CTD/rosette stations (Stations X13-X27, Figure 3) were conducted across the shelf-break north of Elephant Island.

7. A small-area acoustic survey (Survey F, Figure 4) was conducted north of Elephant Island. The survey was conducted at a ship's speed of approximately 10 knots, 17 hours per day over a 3-day period. Directed IKMT and MOCNESS tows were conducted during the dark hours.

8. As part of the CCAMLR Inspection Program, the Polish F/V *Lyra* was boarded and inspected on March 11 north of Elephant Island.

9. Continuous underway measurements were similar to those recorded during the Southbound transit and Leg I.

10. Observations of the distribution and behavior of birds and marine mammals were conducted.

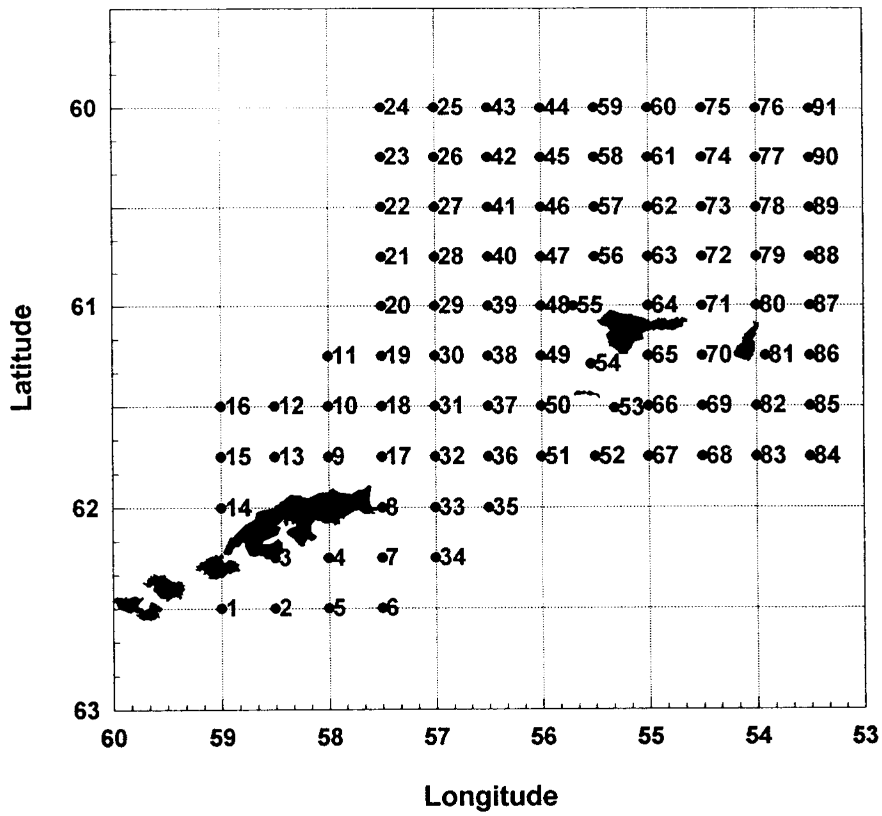

Figure 2. The large-area surveys for AMLR 93 (Surveys A and E).

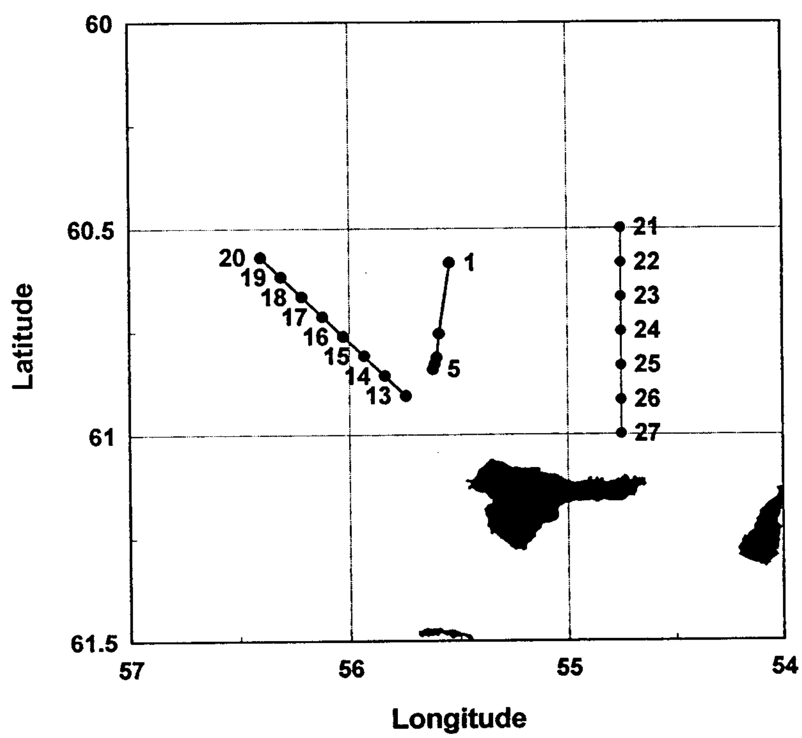

Figure 3. Cross-shelf transects, Stations X1-X5 and X13-X27.

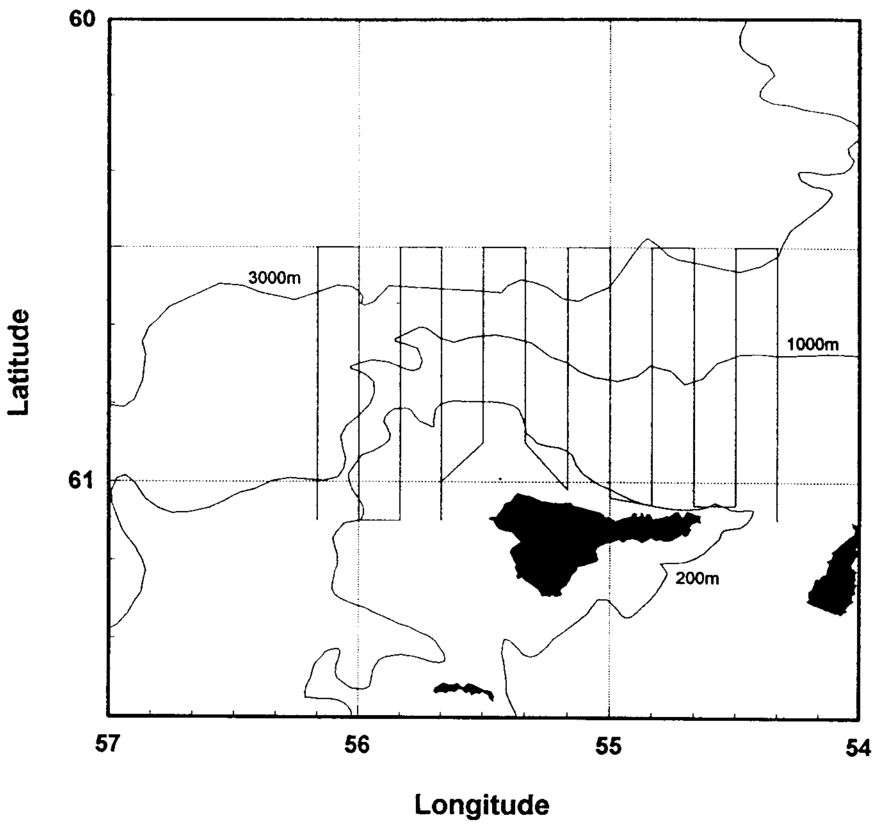

Figure 4. The small-area surveys for AMLR 93 (Surveys B, C, D, and F).

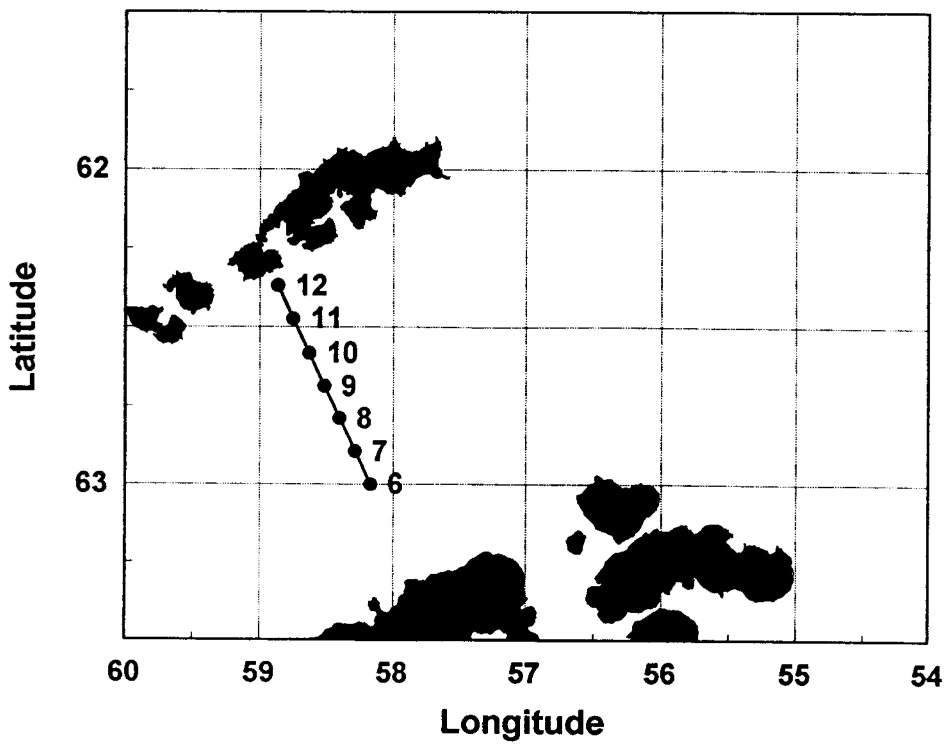

Figure 5. Bransfield Strait transects, Stations X6-X12.

Land-Based Research:

Seal Island

1. The five person field team (J. Bengtson, J. Jansen, W. Meyer, M. Schwartz, and B. Walker) arrived at Seal Island on 4 December 1992. The field team reactivated the field camp. On 14 January 1993, a sixth member (R.V. Miller) arrived at the island by way of the *Surveyor*; fresh supplies were also delivered.

2. Radio-transmitters were attached to 40 female fur seals in early December in order to study at-sea foraging trip duration and attendance ashore. Fifteen of the 40 females were also instrumented with time-depth recorders (TDRs) to document diving behavior as a measure of foraging effort expended by females while at sea.

3. Fur seal pups were weighed at approximately two week intervals throughout the field season. Pups (both alive and dead) were counted daily at the main breeding colonies (North Cove and North Annex), as well at a small breeding colony (Big Booté). Also, a census of the fur seal breeding colony on Large Leap Island was conducted in late January.

4. All classes of fur seals present on the island were censused at approximately weekly intervals. Daily observations of tagged fur seals were conducted to estimate survival, reproductive rates, and tag loss. Also, some previously untagged adult fur seals and fur seals pups were tagged.

5. Fur seal feces were collected at biweekly intervals.

6. Three female fur seals were instrumented with specialized rapid pulse emitting radio transmitters as part of the testing of a new automatic direction-finding (ADF) system; 9 chinstrap penguins were also instrumented.

7. Weekly censuses of other pinnipeds were conducted.

8. *Surveyor* embarked J. Bengtson and J. Jansen on 5 February to return to the United States. The ship returned again to the island on 17 February to offload fresh supplies.

9. In early December, penguin census, breeding success, and breeding chronology studies were begun. Two reproductive study plots were set out (North Cove and Parking Lot), and an initial chinstrap penguin nest census was also completed.

10. A total of 40 adult chinstrap penguins were instrumented with radio transmitters to monitor duration of foraging trips. Forty-nine chinstrap penguins were equipped with TDRs to provide information on diving behavior.

11. Thirty-five stomach content samples of chinstrap penguins were collected for diet studies.

12. A food load delivery study for chinstrap penguins, in which 3 nests were placed atop remote weighing scales, was conducted in the early part of the field season.

13. The number of breeding pairs in all penguin colonies was counted. Three censuses were made of 10 geographically discrete chinstrap penguin colonies undisturbed by other activities. Five macaroni colonies were also censused.

14. To estimate annual survivorship and recruitment into the breeding population, 2,000 chinstrap and 76 macaroni penguins chicks were banded.

15. The growth rates of chinstrap and macaroni penguin chicks were monitored by measuring the weight, culmen length, culmen depth, wing length, and noting the status of the juvenile plumage.

16. The breeding success of 95 accessible cape petrel nests was estimated by surveying nests 5 times during the season. Seventy-six cape petrel chicks were banded.

17. Daily radio communications were maintained with Palmer Station until the *Surveyor* arrived in the study area in mid-January. After that, communications were maintained with the *Surveyor*, the M/V *Explorer*, the R/V *Knorr*, the M/V *Polar Princess*, and biologists at various antarctic science stations.

18. On 10 March, the field team was recovered by the *Surveyor*, and the field camp was closed.

<u>Palmer Station</u>

1. One hundred Adelie penguin nests on Humble Island were followed from clutch initiation to creche.

2. On 6 January, the proportion of 1 and 2 Adelie penguin chick broods was assessed at 54 colonies in 5 different rookeries; on 26 January these and other colonies were censused to assess chick production.

3. Adult Adelie penguins were captured and lavaged (stomach pumping using a water offloading method) for diet composition studies. The resulting samples were processed at Palmer Station.

4. Adelie penguin chicks were weighed during fledging at beaches near the Humble Island rookery.

5. Radio receivers and automatic data loggers were deployed at the Humble Island rookery to monitor presence-absence data on 40 breeding Adelie penguins instrumented with small radio transmitters.

6. One-thousand Adelie penguin chicks were banded as part of long-term demographic studies at AMLR colonies on Humble Island.

7. A 100-nest sample was established at Humble Island to assess the chronology of breeding events.

SCIENTIFIC PERSONNEL

Cruise Leader:
Rennie S. Holt, Southwest Fisheries Science Center (Leg I)
Roger P. Hewitt, Southwest Fisheries Science Center (Leg II)

Physical Oceanography:
Margaret Lavender, University of Texas at Austin (Southbound transit)
Anthony F. Amos, University of Texas at Austin (Leg I)
Charles Rowe, University of Texas at Austin (Legs I and II)
Andrea Wickham, University of Texas at Austin (Leg II)

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Virginia Villafañe, Scripps Institution of Oceanography (Leg I)
Sandra Rivera, Universidad Nacional de la Patagonia, Argentina (Leg I)
Aldo Aguilera, Universidad Austral de Chile (Leg I)
Patricio Moran, Universidad del Sur, Argentina (Legs I & II)
Samuel Hormazabal, Universidad Católica de Valparaiso, Chile (Legs I & II)
Osmund Holm-Hansen, Scripps Institution of Oceanography (Leg II)
Livio Sala, Universidad Nacional de la Patagonia, Argentina (Leg II)

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George Watters, Southwest Fisheries Science Center (Leg I)
Renzo Follegati, Universidad de Antofagasta, Chile (Leg I)
Valerie Loeb, Moss Landing Marine Laboratories (Legs I and II)
Ned Laman, Moss Landing Marine Laboratory (Legs I & II)
David Low, Oregon State University (Leg II)
Sue Kruse, Alaska Department of Fish and Game (Leg II)
Luis Rodriguez, Universidad de Antofagasta, Chile (Leg II)

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Robert Bistodeau, Southwest Fisheries Science Center (Leg I)
Jane Rosenberg, Southwest Fisheries Science Center (Leg II)
Yendo Hu, University of California at San Diego (Leg II)

Seabird and Cetacean Ecology:
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Daniel Grunbaum, University of Washington (Leg I)
Emily Silverman, University of Washington (Leg I)
Beverly Agler, College of the Atlantic (Legs I & II)
David Secord, University of Washington (Leg II)
Gabrielle Nevitt, University of Oregon (Leg II)
Martha Groom, University of Washington (Leg II)

Bird and Marine Mammal Observations:

Larry Spear, Point Reyes Bird Observatory (Southbound transit)
Dan Christian, Point Reyes Bird Observatory (Southbound transit)

Passage transect and PAH Sampling:

Christian Bonert Anwandter, Serv. Hydro. y Ocean. de la Armada, Chile (Leg II)

Seal Island Field Team:

John Bengtson, National Marine Mammal Laboratory
John Jansen, National Marine Mammal Laboratory
William Meyer, National Marine Mammal Laboratory
Michael Schwartz, National Marine Mammal Laboratory
Brian Walker, National Marine Mammal Laboratory
R.V. Miller, National Marine Mammal Laboratory

Palmer Station:

William Fraser, Old Dominion University
Wayne Trivelpiece, Old Dominion University
Brent Houston, Old Dominion University
Donna Patterson, Old Dominion University
Elise Stephens, Old Dominion University
Lucy Keith, Old Dominion University

DETAILED REPORTS

1. Physical oceanography; submitted by Anthony F. Amos (Leg I), Charles Rowe (Legs I and II), Andrea Wickham (Leg II), and Margaret Lavender (Southbound transit).

1.1 Objectives: The physical oceanography component of the AMLR program provided the means to identify contributing water masses and environmental influences within the study area, as well as log meteorological and sea surface conditions annotated by the ship's position. The instrumentation and data collection programs served as host to the other scientific components of the program. The objective of the investigators is to form a credible model of the Elephant Island study area. AMLR 93 is the fourth field season for the collaboration of physical measurements with biological studies.

1.2 Accomplishments:

CTD/Rosette Stations: Ninety-six (96) CTD/rosette casts were made during Leg I, and one hundred thirteen (113) were made during Leg II of AMLR 93. The major effort was the large-area survey of ninety-one stations designated A1 through A91 on Leg I, and E1 through E91 on Leg II. A short cross-shelf transect of five stations (X1-X5) was made while waiting to go into Seal Island on Leg I. During Leg II, a transect was made across Bransfield Strait consisting of seven stations (X6-X12). Two cross-shelf transects were also made consisting of fifteen stations (X13-X27). Almost two thousand water samples were collected from the rosette bottles. The samples were analyzed for micronutrient concentration, phytoplankton, and chlorophyll by the phytoplankton group and for salinity by *Surveyor's* Survey Technicians. One thousand eight-hundred twenty seven (1827) salinity samples were analyzed aboard using a Guildline Autosal to verify the depth that each bottle tripped and to provide calibration data for the CTD conductivity sensor.

Underway environmental observations: Twenty-eight days of continuously acquired weather, sea temperature, salinity, water clarity, chlorophyll, and solar radiation data were collected during Leg I of AMLR 93. Twenty-six days of data were collected during Leg II. Augmented with ship's navigational information these data provided complete coverage of surface environmental conditions encountered throughout the AMLR field season. This year, data from the three shipboard systems (GPS, WEATHERPAK and Thermosalinograph) were provided via serial interfaces directly to the University of Texas Marine Science Institute (UTMSI) data acquisition system resulting in a much higher degree of reliability. The system was set up in Seattle and operated during the transit to Punta Arenas. This also contributed to the high level of data recovery. Unfortunately, the relative humidity sensor was damaged by water intrusion and was inoperable. A replacement was delivered to Punta Arenas for Leg II.

A University of Texas Zeno (Coastal Climate Co.) weather station installed last year on the hill above the Seal Island camp was left over winter. It functioned until October

1992, but suffered damage resulting in limited wind data recovery. UTMSI left the repaired instrument on Seal Island until it was recovered with the Seal Island field party at the end of Leg II. It worked alongside a new Zeno belonging to the AMLR program.

1.3 Methods:

CTD/Rosette: The water profiles were collected with a Sea-Bird model SBE-9 PLUS CTD. This upgraded version of the CTD used on previous cruises enhanced accuracy and software. CTD profiles were limited to 750m depth (or to within a few meters of the ocean floor when the depth was 750m, or less). A Benthos 12 kHz pinger was attached to the rosette frame. Later, the *Surveyor's* InterOcean pinger was used when the Benthos malfunctioned. New parts arrived and the Benthos Pinger was in place for Leg II. A Sea-Bird dissolved oxygen sensor, Seatech 25cm beam transmissometer, Biospherical Instruments PAR sensor, and a Seatech *in situ* fluorometer interfaced with the CTD provided additional water-column data on each station.

Underway data: Data from twelve environmental sensors were collected, multiplexed, and combined with the GPS navigation information. Ship's position and environmental data were acquired from the *Surveyor's* ETHERNET LAN using a program (LOGUNDER) and the ship's computer. This provided GPS position, ship's course and speed, relative wind speed and direction, air temperature (from a Coastal Climate Weatherpak), and sea temperature and salinity from the ship's Sea-Bird SBE-21 thermosalinograph. Using a Weathermeasure signal-conditioning unit, barometric pressure, air temperature, relative humidity, and sea-surface temperature (from a towed thermistor) data were sent to a Hewlett-Packard 3421A data acquisition unit where they were multiplexed and sent to the Data World computer via IEEE-488 GPIB interface.

Three optical sensors, an Eppley PSP pyroheliometer, a Bisospherical Instruments PAR sensor, and an Eppley TUVR sensor, were mounted on the flying bridge to sense solar radiation relatively unobstructed by *Surveyor's* superstructure and masts. These data were fed directly to the HP multiplexer. Finally, a plumbed sea-water flow-through system provided bubble-free water for a Seatech 25-cm transmissometer and a Turner Designs fluorometer to monitor sea-surface water clarity and chlorophyll fluorescence. The inputs were also fed to the HP 3421A.

Throughout the cruise, a Hewlett-Packard 7475A plotter was used to provide real-time graphical representation of environmental conditions. Daily logs and plots of the data were provided to AMLR investigators and the ship's navigator.

1.4 Results and Tentative Conclusions:

Oceanography: Our analysis at this stage includes the identification and grouping of stations with similar vertical temperature/salinity (T/S) characteristics, the horizontal distribution of temperature, salinity and density, and the implied geostrophic circulation.

We list the basic T/S types below.

TYPE I	Drake Passage water: warm, low salinity water, strong sub-surface temperature minimum ("Winter Water," approximately -1°C; salinity 34.0 ppt.), Circumpolar Deep Water (CDW) near 500 meters.
TYPE II	A transition water: temperature minimum near 0°C, isopycnal mixing below T-min, CDW evident at some locations.
TYPE III	Weddell-Scotia Confluence: little evidence of a temperature minimum, mixing with Type II, no CDW, temperature at depth generally > 0°C.
TYPE IV	Eastern Bransfield Strait water: deep temperature near -1°C, salinity 34.5 ppt., cooler surface temperatures.
TYPE V	Weddell Sea water: little vertical structure, cold surface temperatures (near 0°C).

Figure 1.1 contains scatter diagrams showing the envelope in T/S space of CTD data from both large-area surveys. While details of each water type cannot be discerned from the diagram, the difference between the two major water divisions (Drake Passage and Bransfield Strait) is readily apparent. There is little communication between some of the water types found in the Bransfield and the oceanic waters north of Elephant Island, but mixing of CDW water into the upper water layers is evident in the northeast corner of the survey grid. Figures 1.2a and 1.2b contain plots of the individual T/S curves ("worms") on mercator maps of the AMLR study area for Surveys A and E, respectively. The boundaries of the different water types are shown, but it must be stressed that the divisions are often only approximate.

The complexity of the water column in the NE corner can be seen by the degradation of both the temperature minimum of the winter water and the lack of a clear CDW T-max. This is the western end of the Weddell-Scotia Confluence at this latitude. This year's survey area extended farther to the east than in previous years, especially during Survey E (Fig 1.2b), emphasizing the difference between these regimes. The boundary between Type I and Type II water was about 20km north of its position for Survey A in 1992, but about the same location for the same survey in 1991.

We examine briefly here the dynamic flow as indicated by the slope of the sea-surface relative to 500m (Figures 1.3a and 1.3b). The major feature is the prevailing SW to NE flow across the entire AMLR study area. This flow is intensified in three zones: north of Elephant Island, roughly following the topographic trend of the shelf-break; in a narrow band paralleling the northern boundary of the Bransfield Strait south of King George Island; and a more northerly trend between Elephant and Clarence Islands. As seen before, some meander or eddy-like features in the streamlines were observed northeast of Elephant Island. A similar pattern is revealed if the surface is referenced to 200m, so it is assumed that these patterns are reasonably representative of the mean flow in the upper water column of interest to AMLR. The general pattern is not significantly different between Surveys A and E (Figures 1.3a and 1.3b, respectively), except for some meandering to the flow northwest and east of Elephant Island in the later part of the season.

While it is not possible here to analyze the water column level-by level, the surface (10m) temperature and salinity fields for Surveys A and E are contoured in Figures 1.4 and 1.5. The warmest temperatures and least-saline surface waters are associated with the Drake Passage water, derived in part from the Bellingshausen Sea. Summer heating warmed temperatures to above 3.5°C in the northwest by late February (Fig 1.4 b). Conversely, the coldest surface temperatures and most-saline waters are found in the southwest, typical of Weddell Sea water. Only two stations on Survey A had surface waters below 0°C. No surface water on Survey E was less than 0°C. By late February and early March (Figure 1.4b), the sea surface had nearly reached its peak annual temperature, overwhelming the thin band of water less than 1°C running northeast across the region (Figure 1.4a). In the Bransfield Strait and northeast of Clarence Island, some cooling of surface waters may have begun by March (Figure 1.4b). Surface salinity less than 34 PSU has been shaded in Figure 1.5 to denote the approximate boundary of the Type I water zone. Weddell and Bransfield Strait waters reach 34.4 PSU toward the periphery of the survey area.

It is worthwhile to contrast the surface temperature with that at 100m (Figure 1.6). These cold subsurface layers are coincident with the oxygen maximum and often the chlorophyll maximum. In the Type I zone, the T-Min layer is a remnant of the thick, well-mixed surface layer formed during the winter. By late February this zone has warmed, thinned, and fragmented due to mixing with surface water. It is probable that the sub-surface T-min layer remains in the Type I zone until the next winter. Analysis of the dissolved oxygen data cannot be done at this time. It was noted that the DO values were probably on the low side. Recalibration of the sensor was done at cruise end.

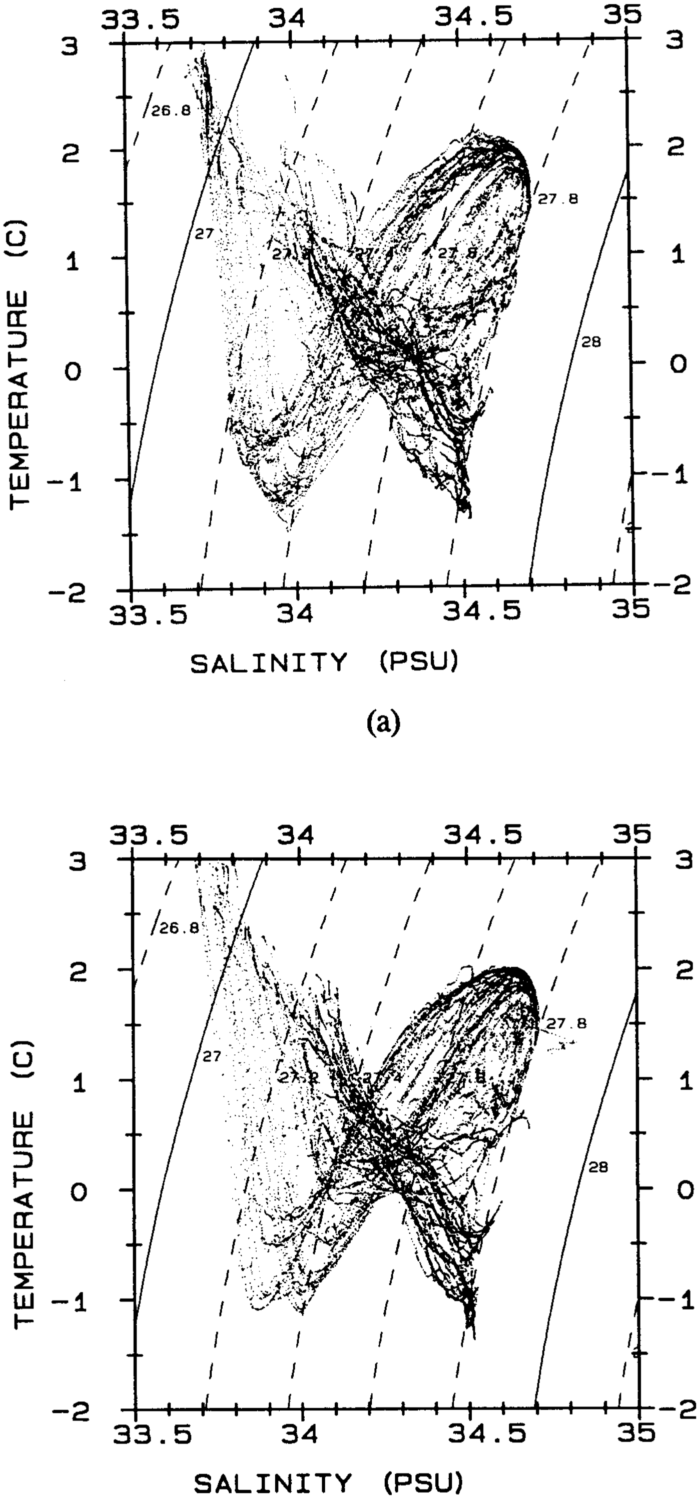
Meteorology: Apart from a couple of periods of winds in excess of 30 knots, the winds were low throughout most of Leg I. A statistical analysis has not been done on the wind-field, but this appears to be one of the calmest AMLR legs to date. How this affected the depth of the mixed layer has yet to be determined. During Leg II, however, there were several periods of high winds. The highest being when the ship was near Deception Island; sustained winds were recorded at 50 knots, with gusts to 80 knots. Air temperatures were above freezing for all but a few hours during the cruise. During Leg I, highs reached as much as 6°C during the large-area survey. The air temperature during Leg II remained within the same range as Leg I. The underway system of programs was upgraded and consolidated during Leg I. A manual was produced covering both hardware and software for this system.

1.5 Disposition of Data: The CTD/rosette, underway, weather station, and XBT data have been stored on Bernoulli 44Mb disks. The raw data will be taken to UTMSI in Port Aransas, Texas, U.S.A. Final analysis will be under the direction of Anthony F. Amos, principal investigator of the physical oceanography component. Copies of the CTD/rosette 1 meter averages and modified 1 minute underway data have been distributed on diskettes to the phytoplankton group. Copies of the printed log sheets and plot were provided daily to the *Surveyor* Bridge, the phytoplankton group, bird observers, and acoustic group.

1.6 Problems and Suggestions: A serial output from the gyro-compass would greatly aid the accuracy of our calculations of ship's heading and speed (and hence true wind speed and direction). Also, a similar output from the single beam of the Seabeam system could provide valuable information for this project. These data would be added to the underway system. Replacing the Everex with another 386 computer made a world of difference to our ability to collect data without interruption and record information on the Bernoulli disks. For future AMLR work aboard *Surveyor*, a permanent replacement for the Everex computer would be most useful.

The after-chart room where the CTD and underway deck electronics are mounted presently have (a) most uncomfortable seating and (b) no storage space (all our equipment is in cardboard boxes under the bench). The addition of a filing cabinet and a few simple drawers would be most welcome. A stool with back support would be most appreciated.

1.7 Acknowledgements: Special mention goes to the electronic technicians for their help during round-the-clock sampling stations; the survey department for setting up the CTD/rosette for each station, collecting water samples, and processing salinity samples; the winch operators for their expert handling of the CTD/rosette under assorted sea conditions; and the Ship's Officers for keeping station and on-deck coordination of operations. Lead electronic technicians, Mark May and Russ Eastman, and especially Andy Miller, deserve our thanks for their assistance in setting up the new CTD and rosette operations which required numerous dismantlings, reterminations, computer-shufflings, and repairs to the rosette. Andy Miller again saved the day when our underway computer had to be replaced toward the end of Leg II.



(a)

(b)

Figure 1.1 T/S scatter diagrams for AMLR 93; all large-area survey stations. (a) Survey A and (b) Survey E.

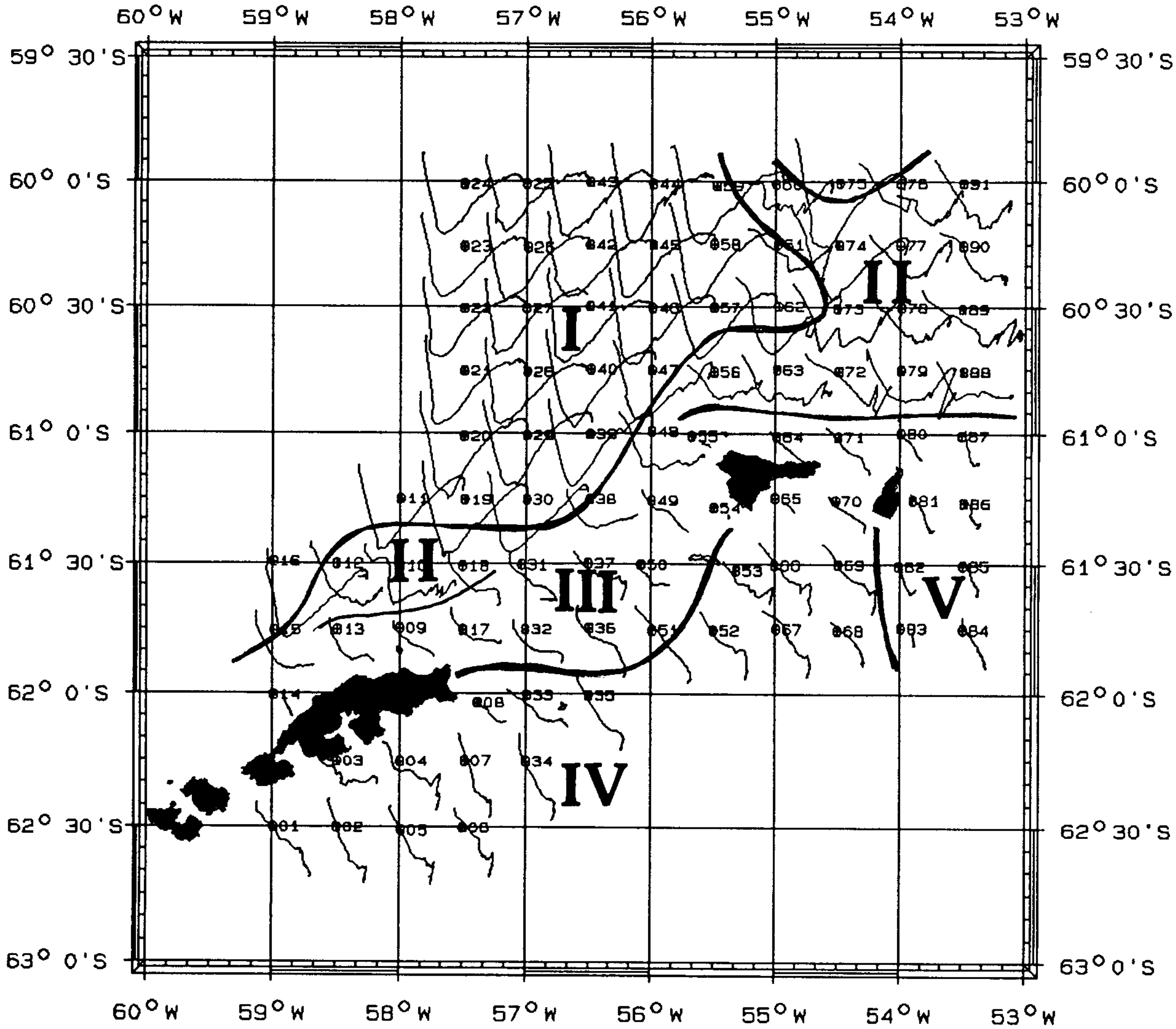
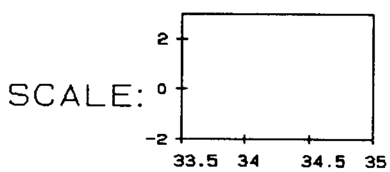


Figure 1.2 AMLR 93. Water Masses Showing Approximate Zone Boundaries
(a) Survey A.



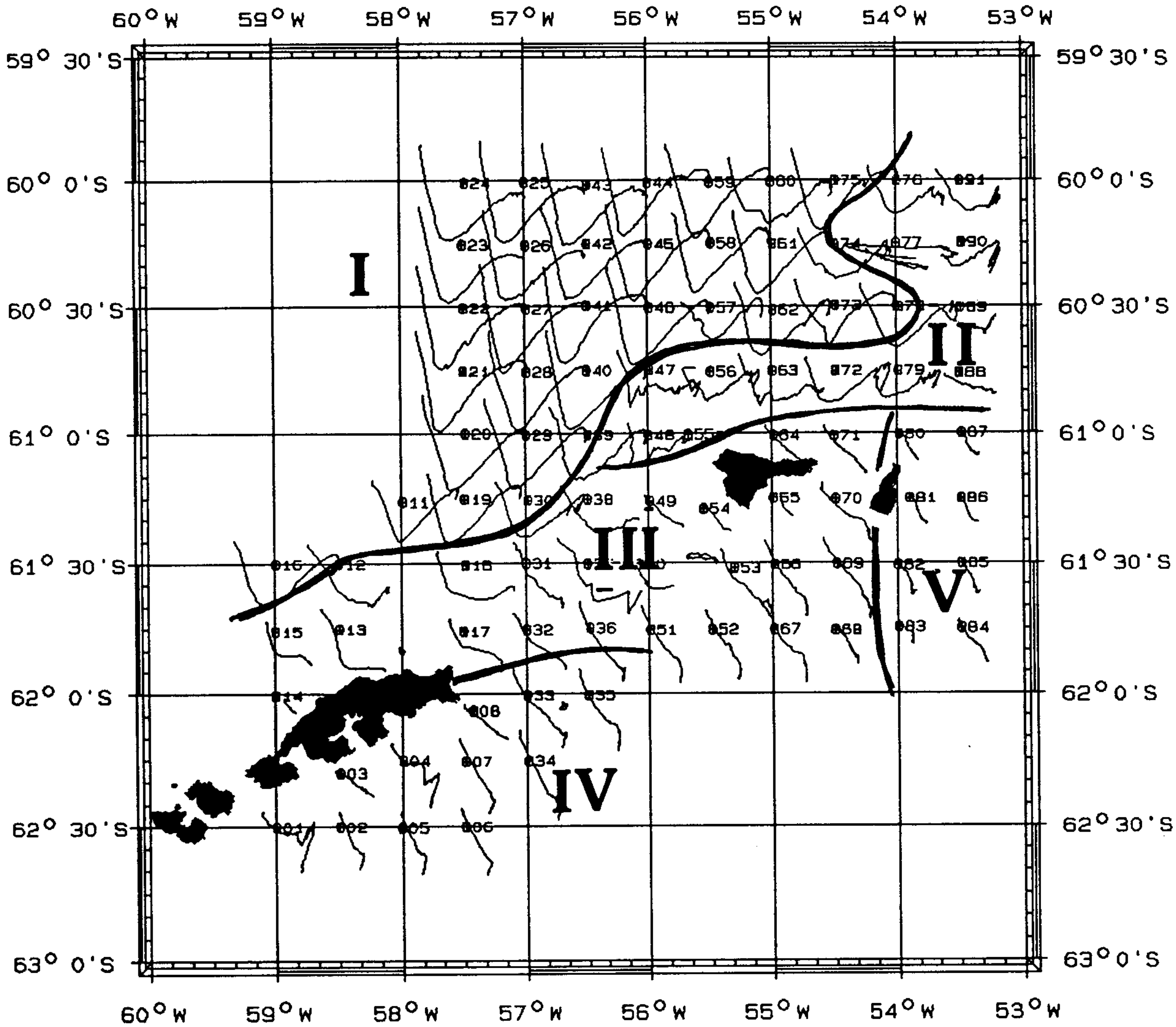
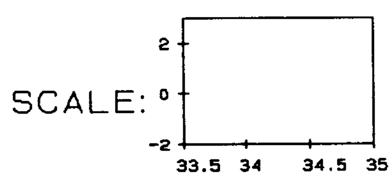
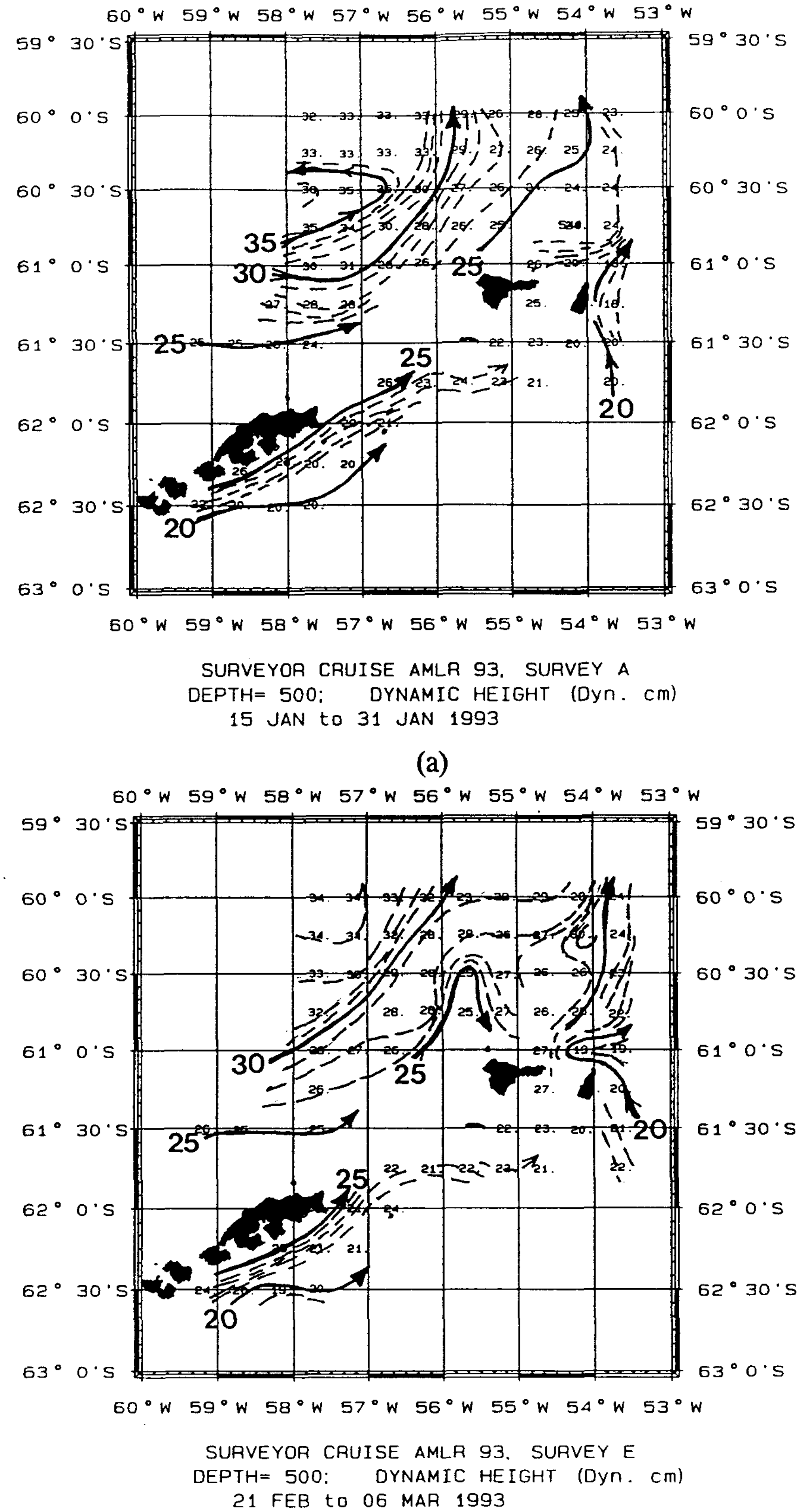


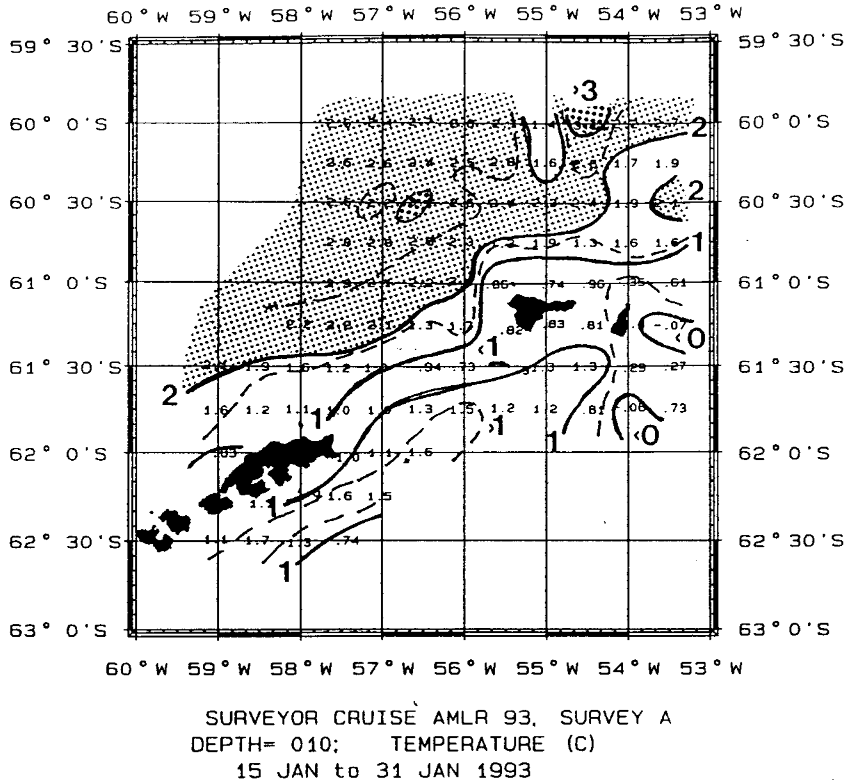
Figure 1.2. AMLR 93. Water Masses Showing Approximate Zone Boundaries
(b) Survey E.



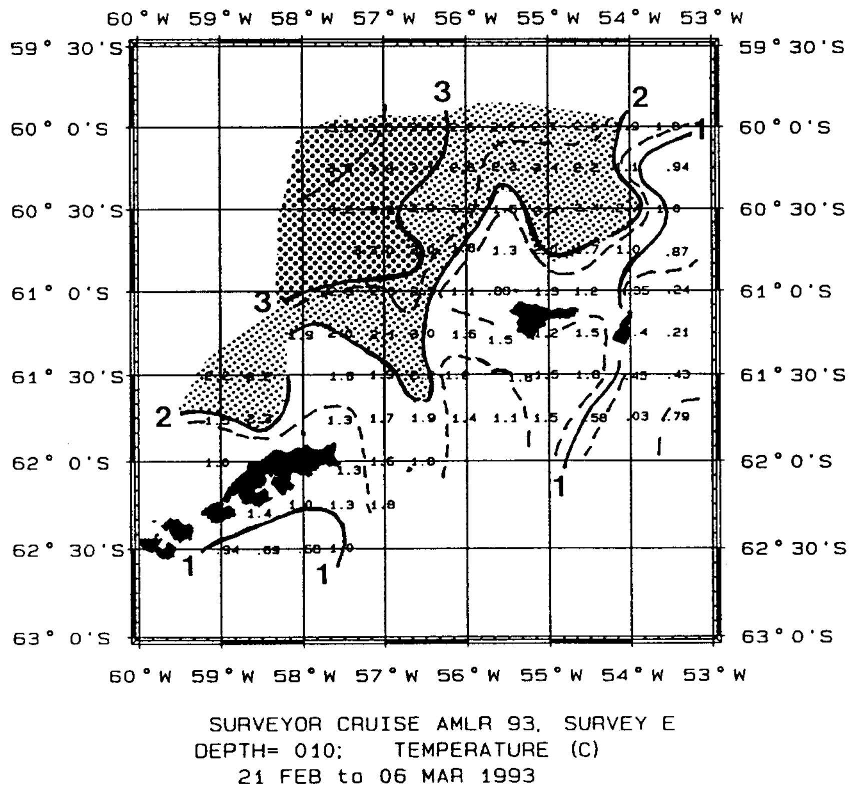


(b)

Figure 1.3 AMLR 93. Dynamic Height of the Sea-Surface Relative to 500dB. Showing Streamlines and Direction of Flow (a) Survey A and (b) Survey E.



(a)



(b)

Figure 1.4 Sea surface (10m) temperatures from large-area surveys. Shaded areas are > 2°C. (a) Survey A and (b) Survey E.

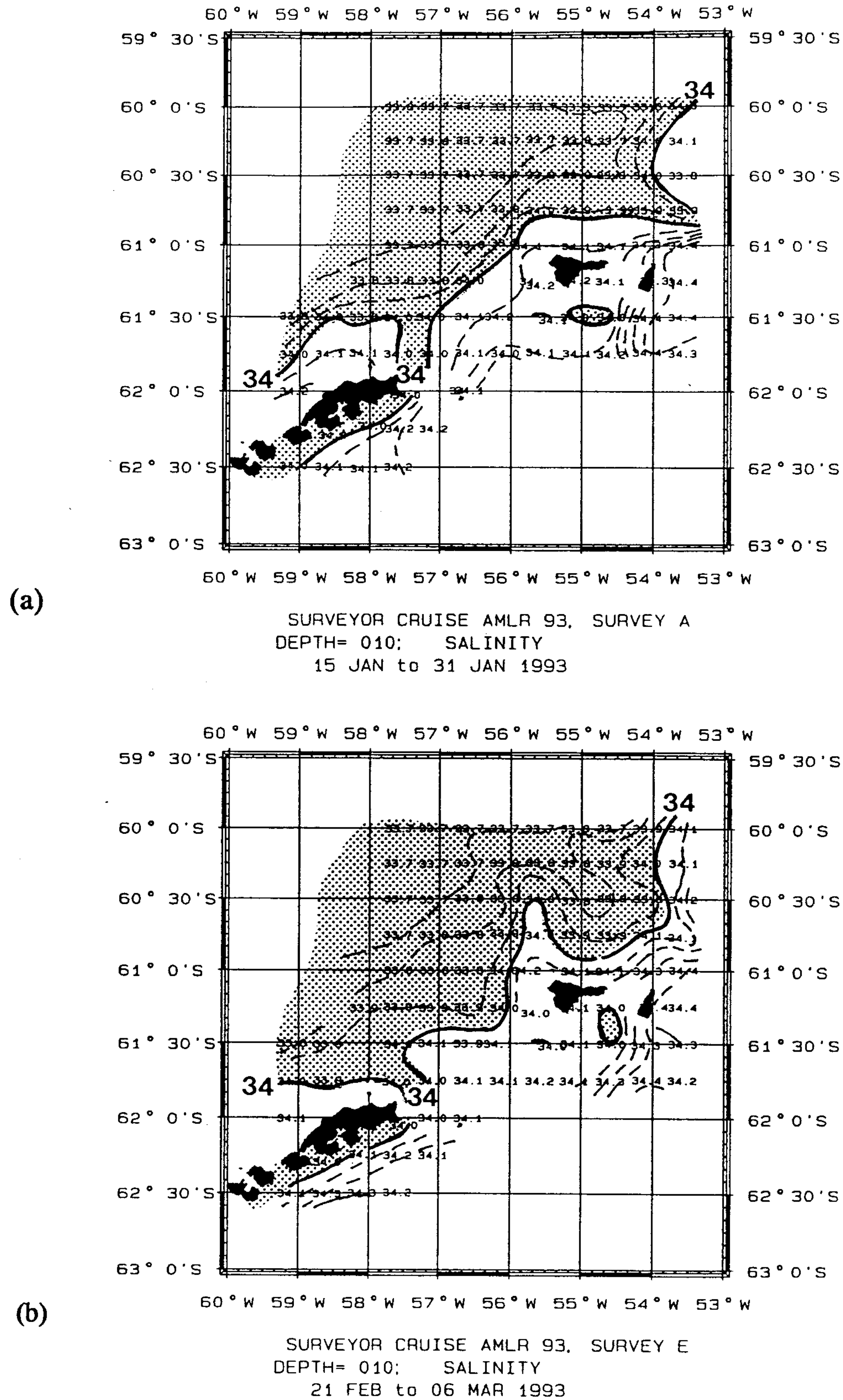
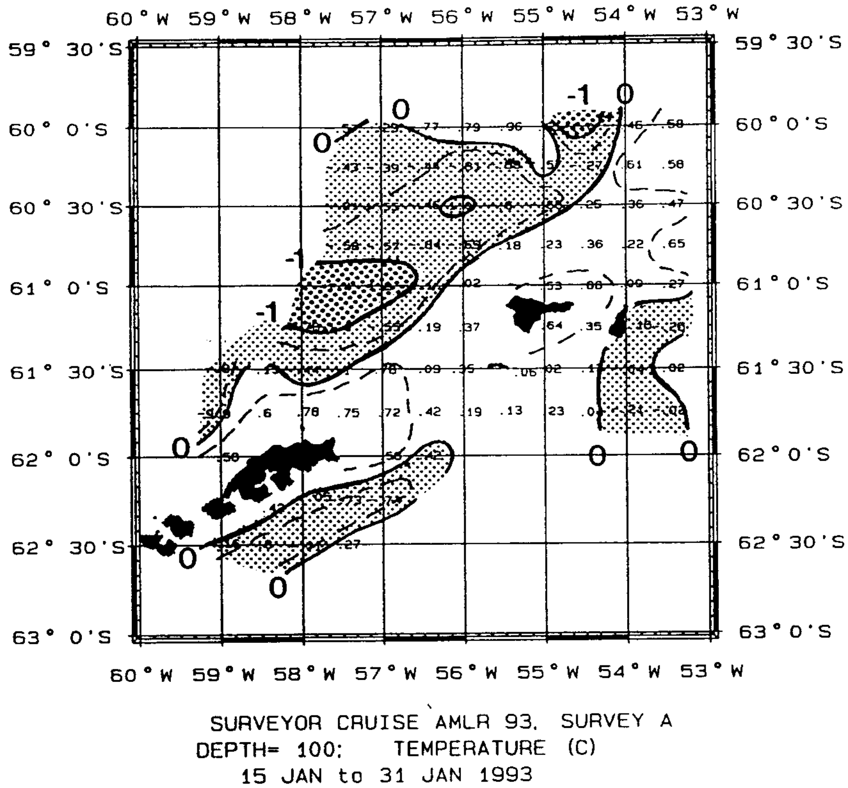
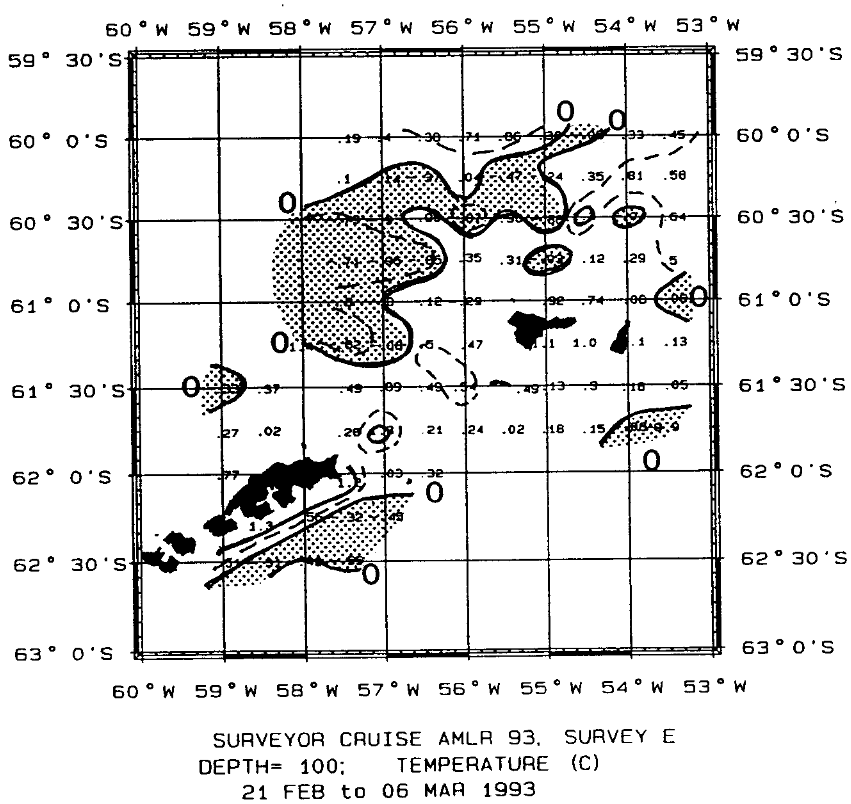


Figure 1.5 Sea surface (10m) salinity from large-area surveys. Shaded areas are < 34 PSU. (a) Survey A and (b) Survey E.



(a)



(b)

Figure 1.6 *In-situ* temperature at 100m from large-area surveys. Shaded areas are < 0°C. (a) Survey A and (b) Survey E.

2. Phytoplankton; submitted by Osmund Holm-Hansen (Leg II), E. Walter Helbling (Leg I), Virginia Villafañe (Leg I), Sandra Rivera (Leg I), Samuel Hormazabal (Legs I and II), Patricio Moran (Legs I and II), Aldo Aguilera (Leg I), Livio Sala (Leg II) and Christian Bonert Anwandter (Leg II).

2.1. Objectives: The overall objectives of our research project were: (1) to document the magnitude and quality of the food reservoir available to grazing zooplankton throughout the AMLR study area, which includes both standing stock estimates as well as rates of primary production; (2) to improve our understanding of the interrelationships between the physical, chemical, and optical regimes that result in maintaining the phytoplankton food reservoir during the growing season; and (3) to develop an ecological model to permit estimation of rates of primary production as a function of depth in the water column by using only automatically sensed data.

An ancillary project consisted of determining the impact of solar ultraviolet radiation (UVR) on phytoplankton primary production, which is important in regard to the seasonal loss of ozone in the stratosphere over Antarctica.

2.2. Accomplishments: The following measurements were done during both legs.

(a) Photosynthetic pigments: Chlorophyll-a (chl-a) concentrations were measured in water samples from 11 depths (surface to 750m or shallower), obtained from every CTD/rosette cast (96 stations in Leg I and 113 in Leg II). In addition, 78 samples from three depths (5, 20 and 50m) were frozen (-20°C) for later determination of *in vivo* absorption spectra (250 to 750nm) of natural phytoplankton assemblages.

Phytoplankton biomass was also estimated by measurement of *in vivo* chl-a fluorescence with pulsed fluorometers. One fluorometer was attached to the profiling CTD-rosette array, while the other unit measured chl-a fluorescence (once per minute) in surface waters throughout the entire cruise by using the ship's clean seawater intake (5m).

(b) Primary production: Rates of primary production were estimated using three different approaches: (1) The standard simulated *in situ* technique: at 26 stations, water samples obtained from eight depths were incubated with radiocarbon to measure rates of primary production under different light levels (from 95 to 0.5% of surface incident radiation) in an incubator with running surface seawater. (2) Experiments were done to measure rates of ^{14}C incorporation using a rotating incubator which simulates the variable light regime experienced by phytoplankton within the mixed layer. The light levels in this incubator ranged from 90 to 3% of surface incident radiation. (3) Primary productivity was also estimated from measurements of upwelling light at 683nm throughout the water column (0-90m) with a hand-deployed instrument (PUV-500) at 21 stations.

(c) Biomass and organic carbon concentration: The following samples and measurements were taken to determine biomass in terms of carbon content: (1) 104 samples for the determination of particulate organic carbon (POC); (2) 268 samples for determination of phytoplankton cell numbers, sizes, and shapes, from which the total cellular volumes and organic carbon will be estimated; and (3) light beam (660nm) attenuation coefficient data were obtained with transmissometers placed in the continuous flow system and on the profiling rosette. The transmissometer data will be used to estimate POC concentrations based on an algorithm developed from past AMLR work.

(d) Phytoplankton cell size and species composition: At every station the following samples were obtained: (1) samples for chl-a determination were filtered-fractionated (Nitex nylon mesh, 20μm pore size) to determine the contribution of the nanoplankton- and microplankton-sized phytoplankton to the total chl-a of the community; and (2) samples were collected from 5m depth for floristic analyses at every station and also from 3 other depths (20, 50, and 100m) at 26 stations distributed throughout the grid. At every other station, a plankton net (20μm) was deployed (horizontal tow for 5 min) to determine net plankton.

(e) Nutrients: Water samples for measurement of nitrite, nitrate, phosphate, and silicate were taken at all stations at four depths (5, 50, 200m and bottom) and kept frozen (-20°C) for later analysis ashore.

(f) Light measurements: The following data on incident solar radiation were collected throughout the study area: (1) continuous monitoring (every minute) of Photosynthetic Available Radiation (PAR, 400-700nm), Total Ultraviolet Radiation (TUVR, 285-385nm), and total light energy from 285 to 2800nm (instruments located on the flying bridge); (2) continuous monitoring (every minute) of PAR and four different channels (308, 320, 340, and 380nm) of ultraviolet radiation (instrument on the helipad adjacent to the incubators); (3) vertical depth recording of the underwater PAR (sensor mounted on the rosette) for measurement of the attenuation of the solar radiation in the water column; (4) hand deployment of a profiling unit to measure PAR, four channels of UVR, temperature, depth, and 683nm upwelling light (down to approximately 100m); (5) a continuous recording of the total light flux during any incubation period using an integrating PAR sensor (mounted adjacent to the deck incubators); and (6) a direct measure of the light flux to the samples (rate-meter PAR sensor inserted into the incubation tubes).

2.3 Results and tentative conclusions:

(a) Chlorophyll-a distribution from extracted values showed high integrated values (from 0 to 100m) in a zone that seems to follow the 1000m depth contour from southwest to northeast in the sampling grid. In general the distribution of chl-a was similar to that of last year, but with much higher integrated values (ca. two times). During Leg I, patches of more than 100mg m^{-2} were observed to the north of King George Island, and to the west and north of Elephant Island (Figure 2.1). The distributional pattern of chl-a during Leg II was similar to that in Leg I, but the chl-a concentrations had decreased markedly (Figure 2.2). The mean chl-a concentrations in surface waters during Legs I and II were 0.88 and 0.30mg m^{-3}, respectively. The integrated (0 to 100m) chl-a concentrations during Legs I and II were 39.8 and 23.3mg m^{-2}, respectively.

(b) During both Surveys A and E, the nanoplankton (less than 20μm) component was a dominant portion (more than 60%) of the total phytoplankton assemblage. However, values ranging between 40 to 60% occasionally appeared at depth (around 100m) in areas of high chl-a concentration and also in the southeast corner of the sampling grid, which is most influenced by Weddell Sea water.

(c) Preliminary analysis of net plankton samples during Leg I (cells bigger than 20μm) showed the predominance of diatoms in all stations, with the chain forming diatom *Rhizosolenia antennata fo. semispina* being characteristic of stations located in the northwest portion of the sampling grid. *Corethron criophilum* was characteristic of stations in the southeast part of the grid. *Actinocyclus actinochilus* was present in a narrow band between these two areas.

(d) Data obtained with our hand-deployed profiling sensor (PUV-500) are presented in Figure 2.3 for two stations, one with low chl-a concentrations (A43, 9.7mg m^{-2}; Fig. 2.3A) and the other with high chl-a values (A77, 88.6mg m^{-2}; Fig. 2.3B). It is seen that the UV-B wavelengths (290 to 320nm), which are most damaging to biological systems, are attenuated quite rapidly in the upper water column.

(e) Typical profiles of the upper water column characteristics (0-250m) at two contrasting stations are presented in Figure 2.4. High phytoplankton biomass was generally observed within the upper mixed layer (UML), but at some stations a small maxima was observed below the UML as revealed by the transmissometer and chl-a data. Note that the attenuation of light (PAR) is very different in these two stations, with the 1% light level being at 110 and 30m for stations A43 and A77, respectively. These differences in distribution of phytoplankton biomass in the upper water column are characteristic of different water masses as described by the physical oceanographic component of AMLR. Data in Figure 2.5 show profiles of chl-a concentrations in a north-south transect (stations A25 to A34 of Survey A), which includes water masses I, II, and IV as described by Amos et al. It is seen that stations in type I water (A25, A29, A30) have low chl-a in the upper 40m, with increased concentrations between 50 to 100m. Stations south of the frontal zone (A31, A33, A34), which are in type II or type IV water, have maximal chl-a concentrations in the upper 40m, with decreasing concentrations below that depth.

(f) Natural solar radiation data for four UVR channels and PAR for the brightest (01/17/93) and darkest (01/25/93) days during Leg I are shown in Figure 2.6. The daily mean irradiance (sunrise to sunset) for PAR during Leg I was 801μE $m^{-2}s^{-1}$. In Figure 2.7, the mean daily (time measured from sunrise to sunset) irradiance data from 01/11/93 to 02/04/93 are presented for four channels of UVR and for PAR.

2.4. Disposition of the data and samples: Measurements of chl-a, natural solar radiation (PAR and UVR), and particle concentrations (transmissometer data) were completed during the cruise. Samples for the following analyses will be processed in the laboratories of the Polar Research Program at Scripps Institution of Oceanography: (a) particulate organic carbon and nitrogen, (b) preserved samples for floristic determination, (c) absorption spectra of particulate material, and (d) radiocarbon samples for primary production determinations. Water samples for inorganic nutrients will be analyzed at the Universidad Católica de Valparaiso, Chile. All data have been stored on computer discs and are available from O. Holm-Hansen at SIO.

2.5 Acknowledgements: We want to express our sincere thanks to all officers and crew of NOAA Ship *Surveyor* for their generous help in all matters relating to work and life on board the ship. We also thank all other personnel of the AMLR program for help, support, and data which enhanced the productivity of the phytoplankton program.

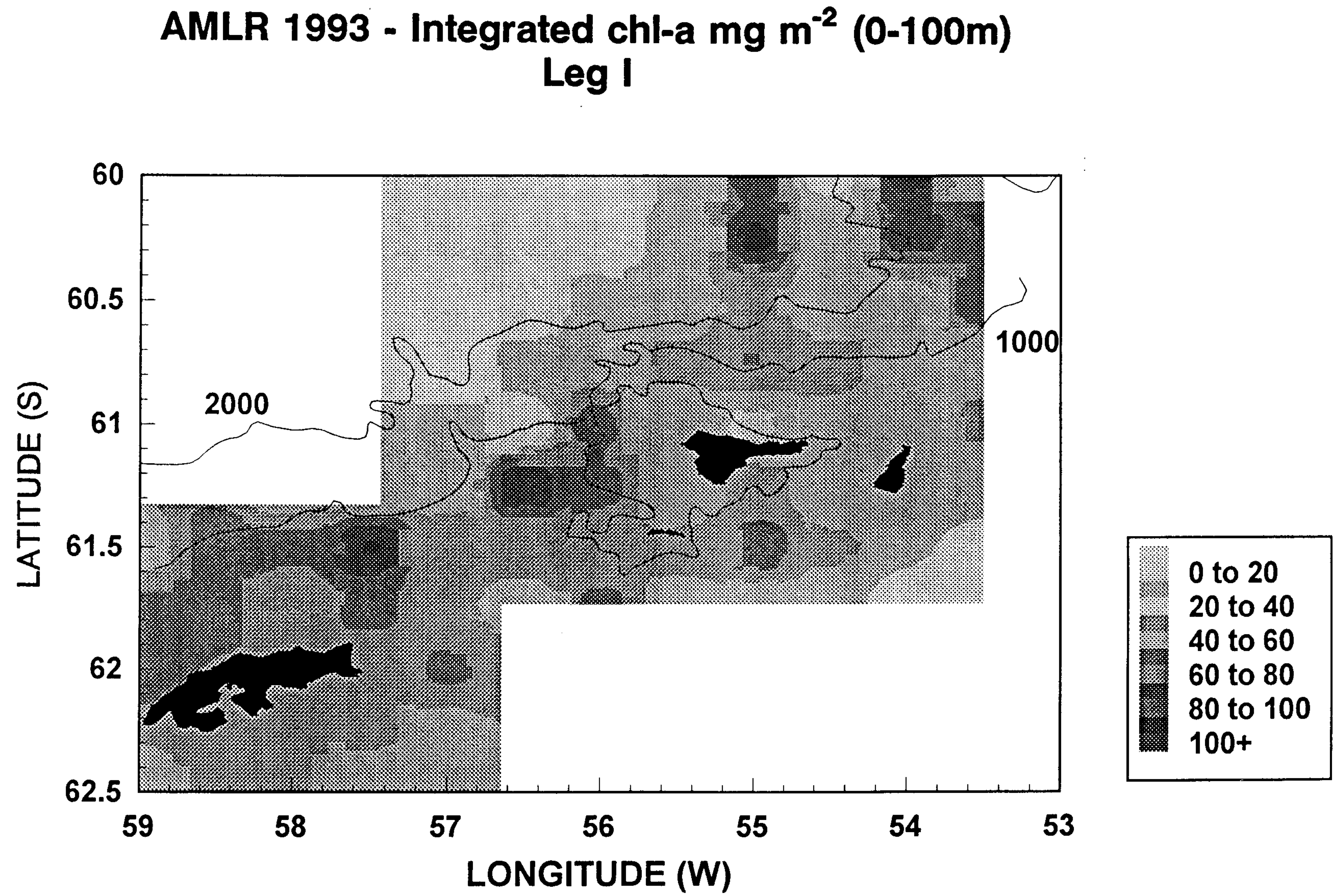


Figure 2.1 Distribution of integrated chl-a (mg m^{-2}) from surface to 100m depth during Survey A. Solid lines indicate contour depth.

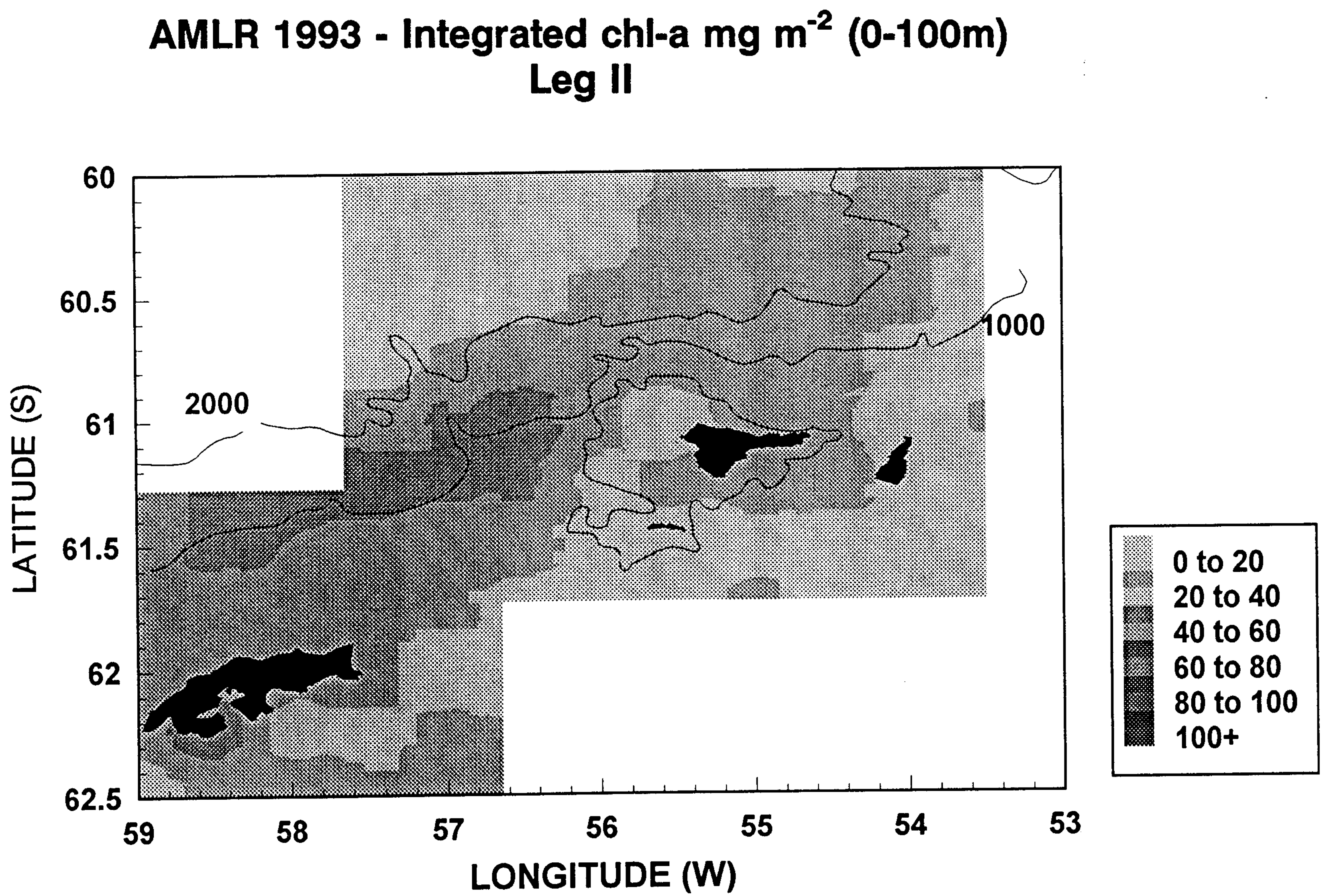


Figure 2.2 Distribution of integrated chl-a (mg m^{-2}) from surface to 100m depth during Survey E. Solid lines indicate contour depth.

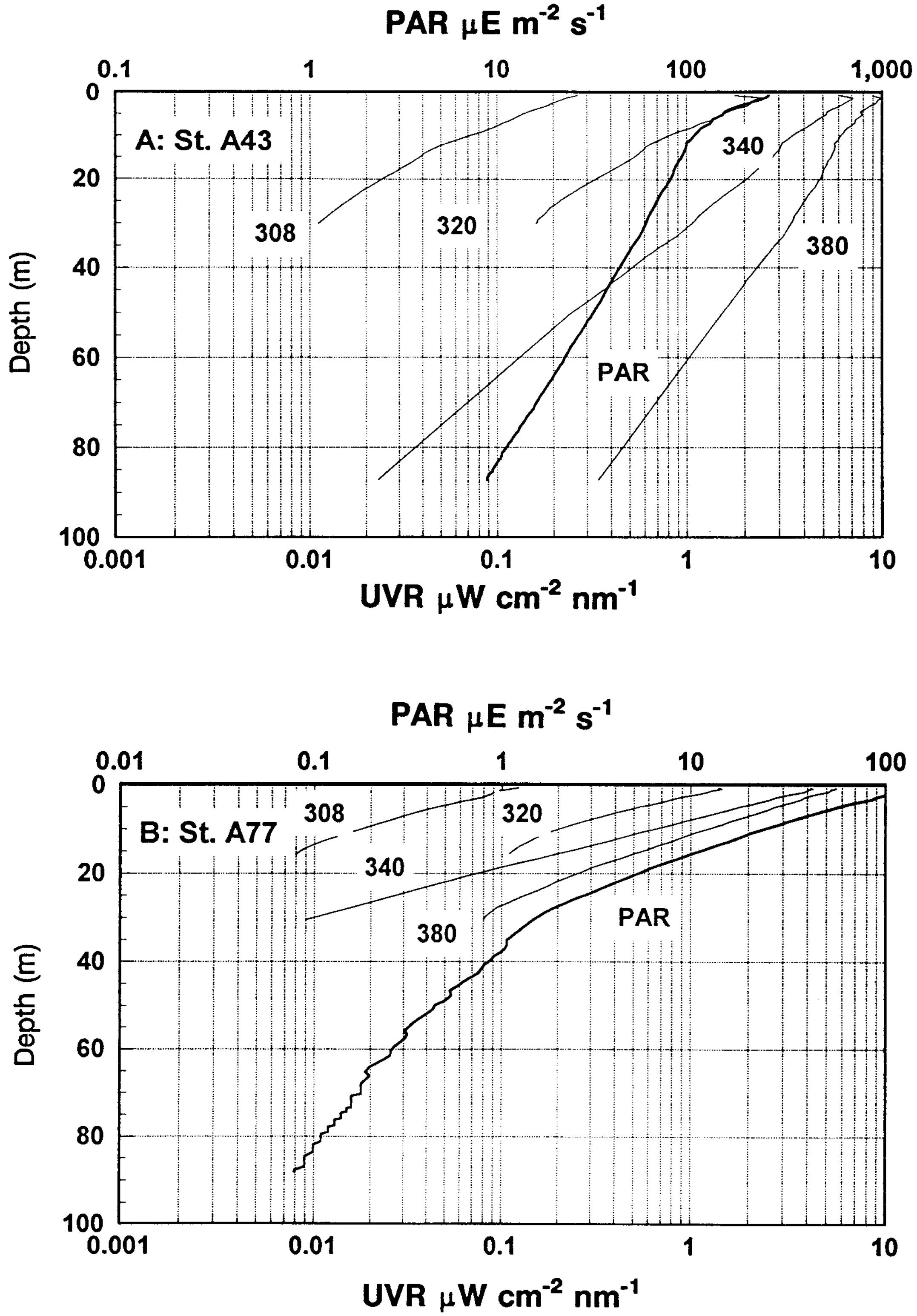


Figure 2.3 Underwater solar radiation measurements for PAR (μE m^{-2} s^{-1}) and UVR (μW cm^{-2} nm^{-1}) for: (A) Station A43, a low biomass station, and (B) Station A77, a high biomass station. Note the different attenuation of radiation between stations.

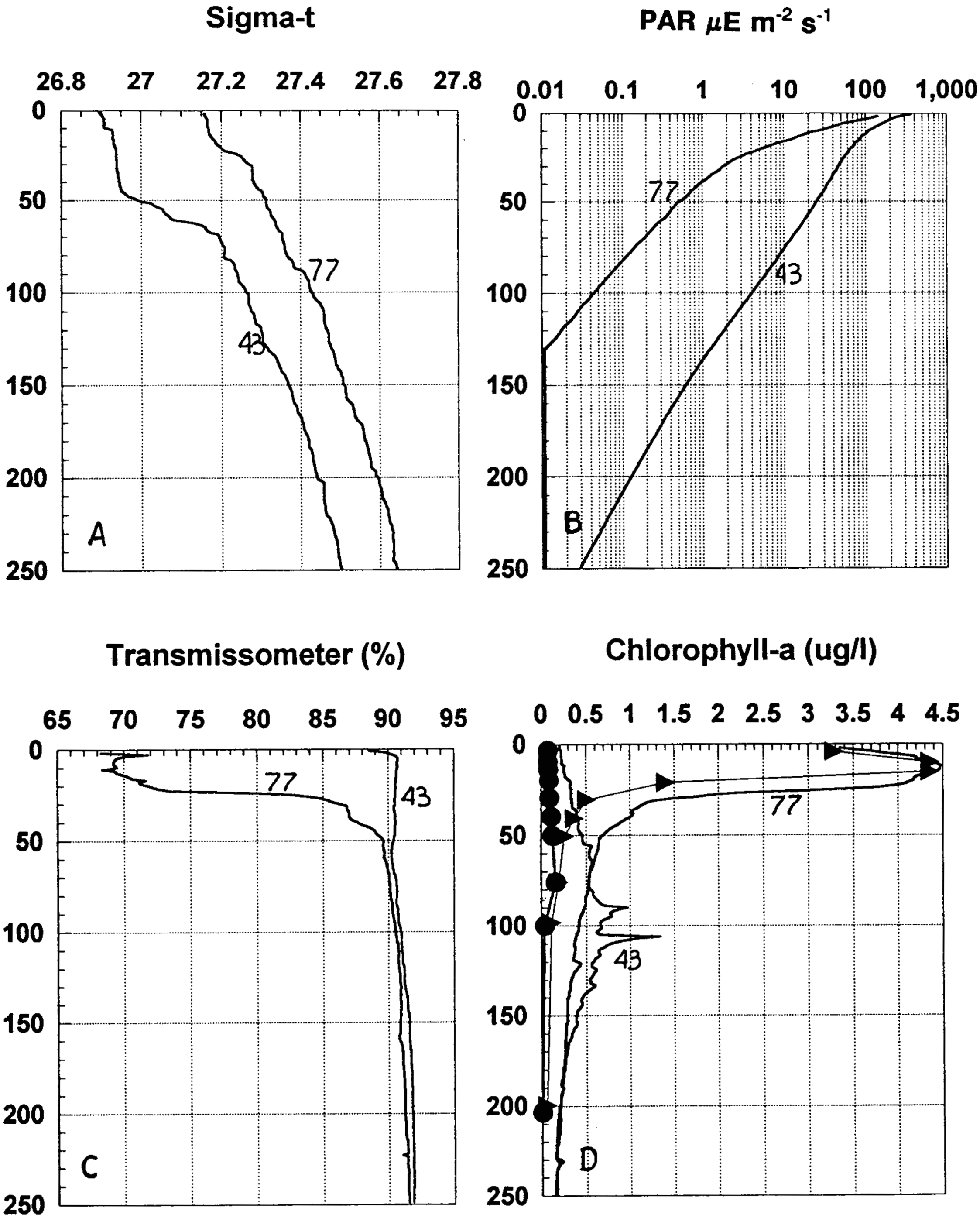


Figure 2.4 Physical-biological characteristics of the upper water column (0-250m) at two contrasting stations, A43 with low chl-a, and A77 with high chl-a. (A) Sigma-t, (B) Photosynthetic Available Radiation (400-700nm), (C) Light transmission in percentage, (D) Vertical distribution of chl-a as measured in extracted samples (lines with symbols) and by *in vivo* fluorescence with a pulsed fluorometer (solid lines).

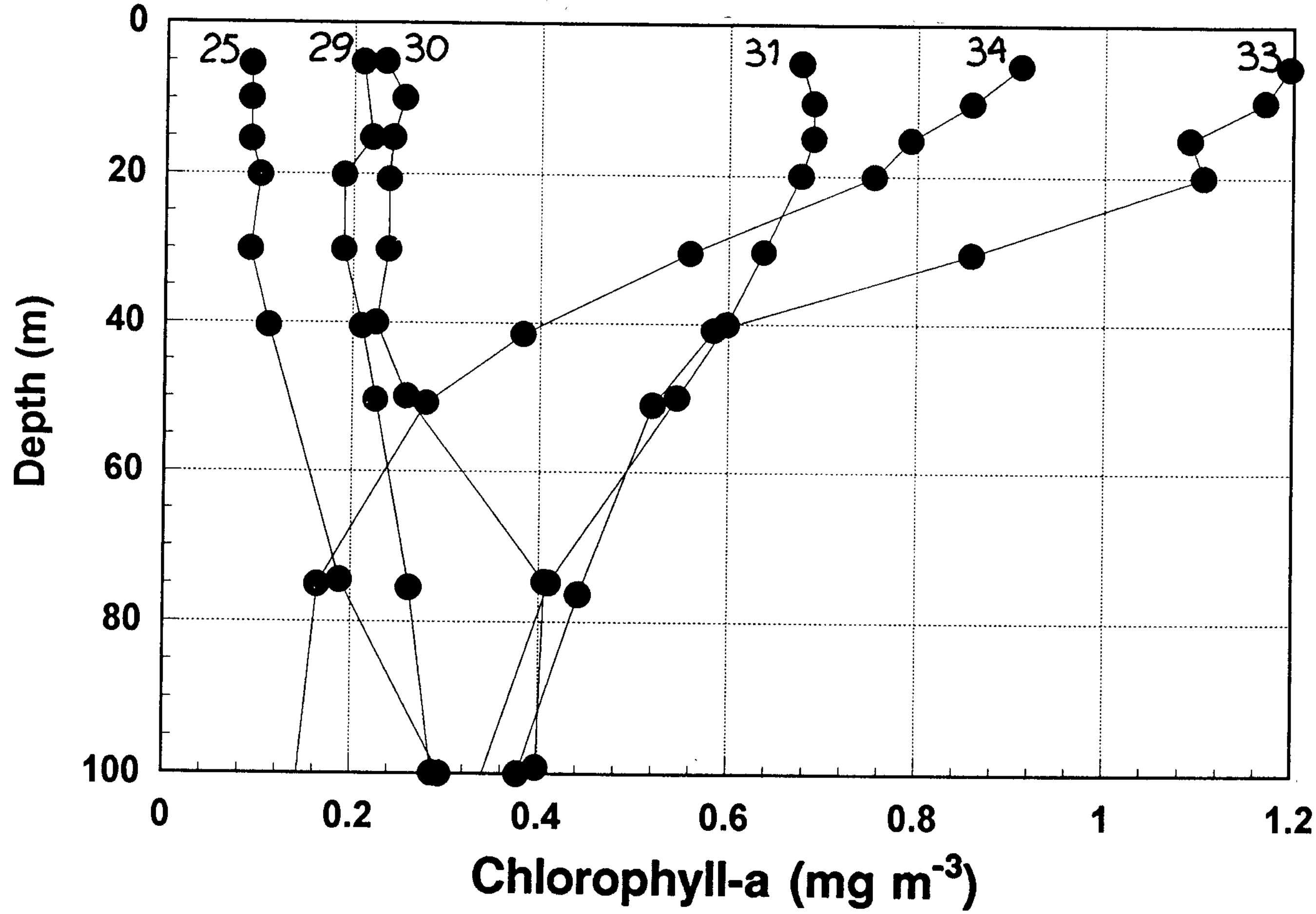


Figure 2.5 Characteristic profiles of chl-a in the upper water column in a north-south transect which cuts across the frontal mixing zone evident from the physical oceanographic data. Stations A25, A29, and A30 lie north of the frontal zone in type I water; stations A31, A33, and A34 lie south of the frontal zone in water types II or IV. Data from Survey A.

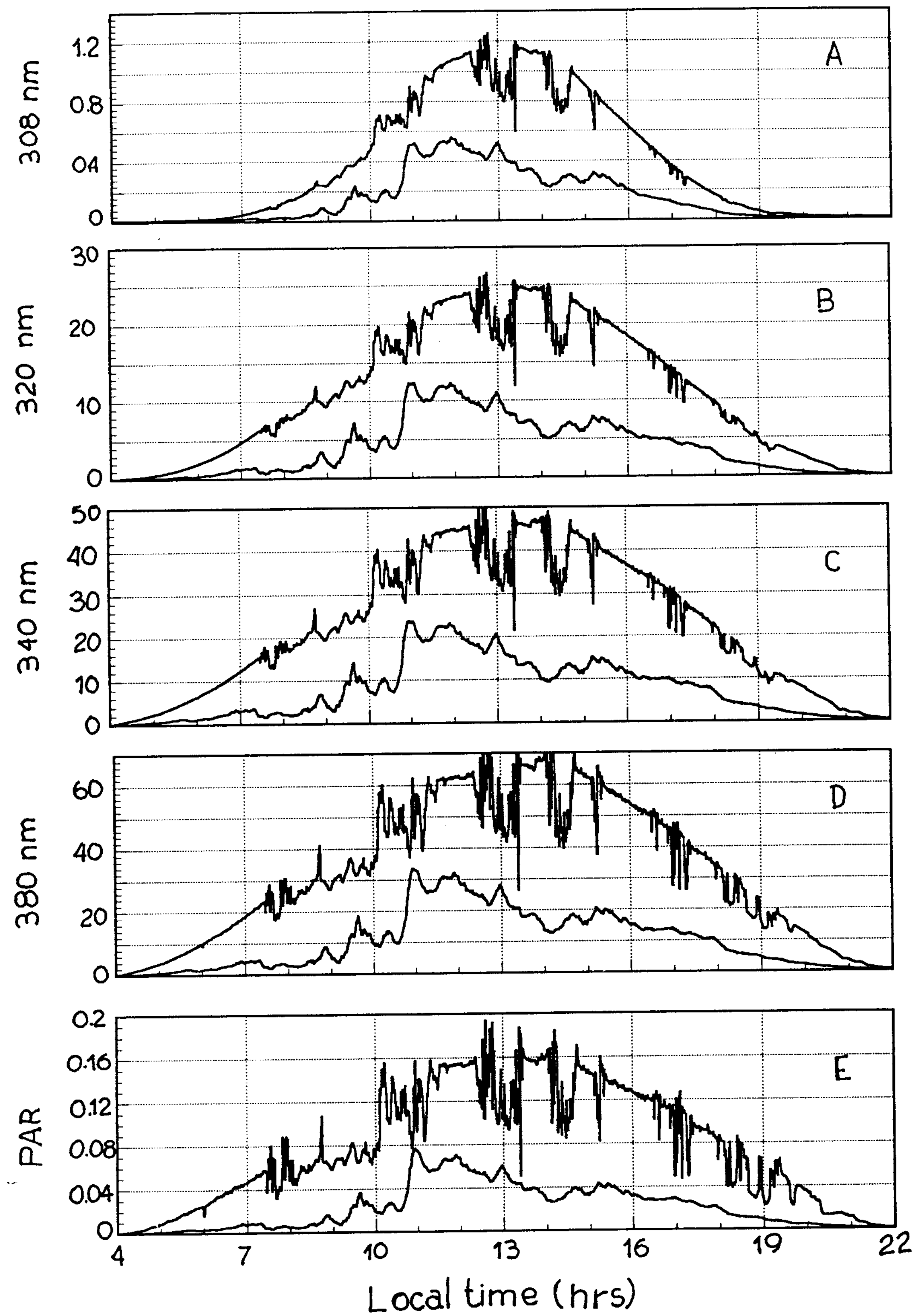


Figure 2.6 Solar radiation data collected on January 17 (upper line in each graph) and January 25, 1993 for UVR (μW cm^{-2} nm^{-1}) and PAR. (A) 308nm, (B) 320nm, (C) 340nm, (D) 380nm, and (E) PAR in μE m^{-2} s^{-1}.

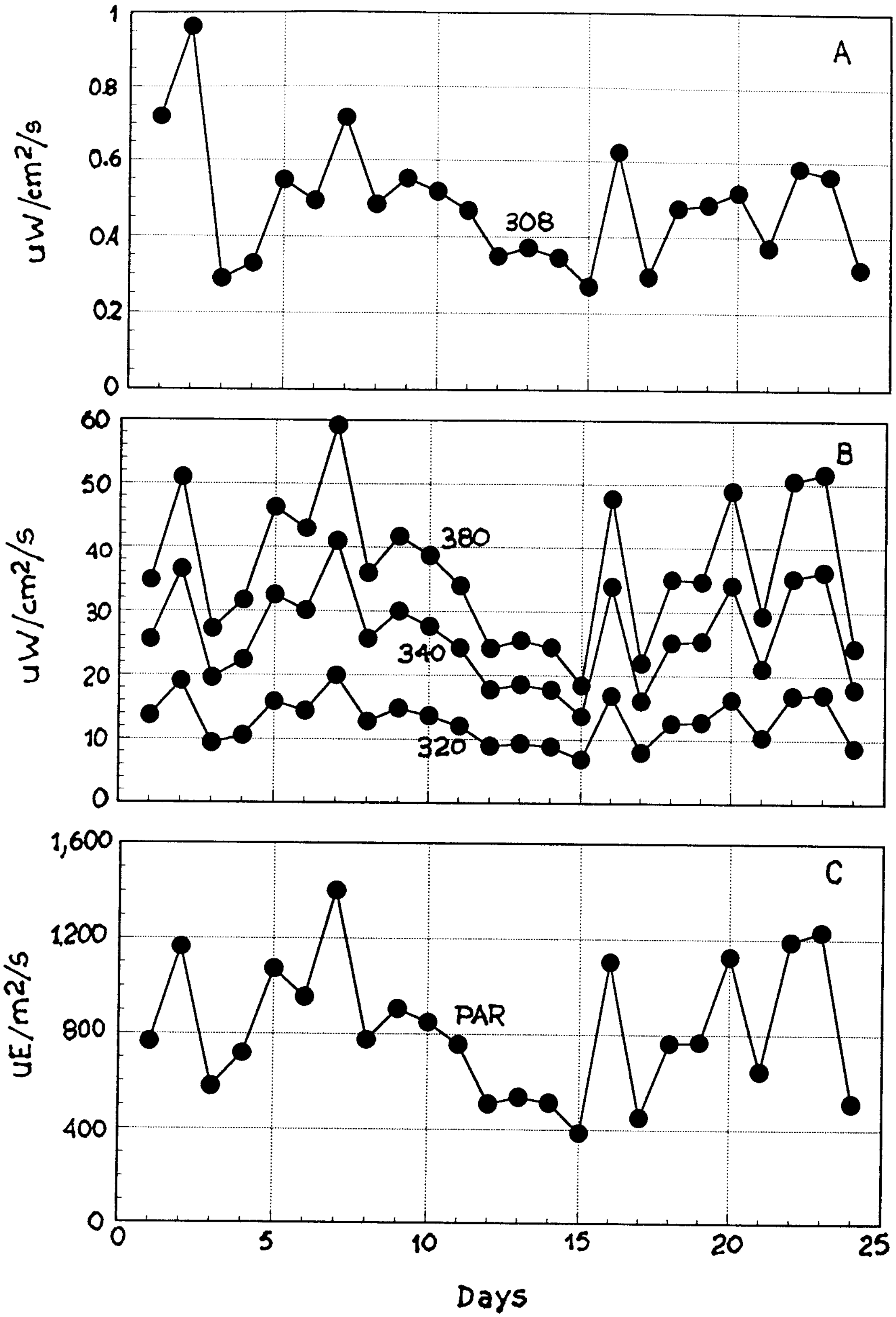


Figure 2.7 Mean daily surface irradiance measurements during Leg I for: (A) UVR, 308nm; (B) UVR, 320, 340, and 380nm; (C) PAR.

3. Bioacoustic survey; submitted by David Demer, (Leg I) Robert Bistodeau (Leg I), Roger Hewitt (Leg II), Jane Rosenberg (Leg II), and Yendo Hu (Leg II).

3.1 Objectives: The primary objectives of the bioacoustic survey were to map the meso-scale and micro-scale distributions of krill (*Euphausia superba*) in the vicinity of Elephant and Seal Islands, estimate their biomass, and determine their association with predators, bathymetry, water masses, phytoplankton and light. Secondary goals included the acquisition of data which may better define krill target strengths, species identification, diel migration patterns, swarm sizes, inter-swarm spacing, and survey optimization.

3.2 Accomplishments: An echo-integration system was used to map and quantify krill over two spatial scales. Two large-area surveys (Surveys A and E) were conducted in the vicinity of Elephant, Clarence, and King George Islands; four small-area surveys (Surveys B, C, D and F) north of Elephant Island were also conducted. The acoustic system was used to collect data over a total of 5500 n.mi. of trackline.

The main components of the acoustic system included a Simrad EK500 Scientific Echosounder, a UNIX workstation with BI500 postprocessing software, the ship's MX200 GPS receiver, and an ETHERNET communication link. Initially, a dead-weight towed body was used to house a 120kHz split-beam and a 200kHz single-beam transducer in a down-looking configuration. A target tow depth of 8-10m was monitored by a time depth recorder (TDR). Following the loss of the dead-weight towed body during the initial portion of Survey A, a v-fin towed body (depressor-type) with a down-looking 120kHz split-beam transducer was used to conduct the remainder of Survey A and all of Surveys B and C. A replacement dead-weight towed body and two new transducers (same specifications as lost transducers) were procured for use during Leg II. All transducers were narrow beam, with 7-9 degrees between half-power points. Pulses were transmitted once per second at 1kW for 1.0ms duration (120kHz) and 0.6ms duration (200kHz). However, the 120kHz pulse was shortened to 0.1ms during net tows to optimize for target strength detections. Geographic positions were logged every 60 seconds. The insonified volumes were roughly conical and sampled to a depth of 250m. A Sun SparcStation 1+ was used for postprocessing, including echo-integration, target strength analyses, and contour mapping. The very high volume acoustic data were processed and stored on 8.0 GB digital audio tapes (DAT), as were the raw data collected during net tows.

Volume backscattering strength data were collected along all transects with breaks only for CTD stations. These data were integrated from approximately 15 to 250m in depth and averaged over 0.1 n.mi. track-line increments. The resulting data are proportional to biomass. Acoustic target strength measurements (TS) were made during each of the IKMT net tows as part of each station. These data will be used to develop TS versus krill length relationships and to refine the proportionality constant for biomass estimation.

3.3 Tentative Conclusions:

Survey A: The first large-area survey covered an area of roughly 15,000 n.mi.^{2} centered between Elephant and King George Islands. The survey was comprised of 12 north-south transect lines, averaging approximately 105 n.mi. in length, with 15 n.mi separating each line. A CTD cast and an IKMT net trawl were conducted at stations spaced 15 n.mi apart along each line. A topographic map of krill density was created by interpolating integrated volume backscattering strength data between north-south tracklines (Figure 3.1). This map revealed large scale krill distributions which are consistent with austral summer 1992. High density areas are evident to the northwest of Elephant Island. Additionally, high density areas are located between Elephant and Clarence Islands and to the west between Elephant and King George Island. In general, these distributional patterns correspond to shallow water and the outer limits tend to follow the 200m depth contour. High krill concentrations are also marked by intermediate to low chlorophyll-a in the upper 100m. IKMT data display only vague agreement with the krill distributions depicted in Survey A.

Survey B: Following the completion of the large-area survey, a small-area acoustic survey was conducted continuously for three days to the north of Elephant Island. The purpose of this survey was to better define the fine-scale distributional patterns of krill which are near predators (penguins and seals) residing on Seal Island. The survey grid consisted of twelve north-south transect lines, each approximately 35 n.mi. long with 5 n.mi. separating each line. The integrated volume backscattering strength was again interpolated over the entire survey area and plotted topographically (Figure 3.2). This map revealed the location of a dense krill population around the northeast edge of Elephant Island and small patches in deeper water to the north and northeast. A large mass of krill to the northwest of Elephant Island (as mapped in Survey A) had dispersed significantly.

Survey C: A second small-area survey was conducted; however, due to lack of time, only half of the survey was completed. During this survey, acoustic transects were conducted 16 hours per day, centered on local apparent noon. The two day survey was augmented with acoustically directed MOCNESS sampling at night. This provided data for a study of the diel migration behavioral patterns of krill and their potential impact on acoustic biomass surveys. Directed sampling supplied ground truth data for acoustic species identification and for target strength studies.

Survey D: At the beginning of Leg II, another small-area survey (Survey D) was conducted north of Elephant Island. Similar to Survey C during Leg I, operations consisted of acoustic transects conducted during daylight hours and directed MOCNESS and IKMT net sampling during dark hours. Krill were sparsely distributed throughout the survey area; highest densities were mapped 30 n.mi. northwest of Seal Island and in the immediate vicinity of the island (Figure 3.3). Krill were detected very near the surface during dark hours. Preliminary results from *in-situ* target strength measurements and directed net sampling suggest that salps may be acoustically distinguishable from krill in near-surface layers.

Survey E: Following Survey D, a large-area survey (similar to Survey A of Leg I) was conducted. Low densities of krill were mapped throughout the eastern half of the survey area, except near the northern and southern shores of Elephant Island. In comparison, krill densities in the western half of the grid were higher, with highest densities 50 n.mi. north of Seal Island, 30 n.mi. southwest of Elephant Island, and immediately north of King George Island (Figure 3.4). Overall, krill densities found during Survey E were low in comparison to Survey A, although comparable to a similar survey conducted at this time last year.

Survey F: At the end of Leg II, another small-area survey was conducted. As in Surveys C and D, acoustic transects were conducted during daylight hours and directed MOCNESS net sampling was done during dark hours. Krill densities were higher than those observed on previous surveys conducted during Leg II, particularly over the western portion of the survey (Figure 3.5). Krill densities were highest immediately adjacent to Seal Island and 30-40 n.mi. north of the island.

3.4 Disposition of Data: Integrated volume backscattering data will be made available to other investigators in MS-DOS or UNIX (Sun-OS) format ASCII files. The analyzed echo-integration data, averaged over 0.1 n.mi. intervals, consume approximately 10 MB. The raw data collected during the IKMT net tows total about 12 GB in binary form and are currently archived on DAT tapes. All data are available from David Demer, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037.

3.5 Problems and Suggestions: In past field seasons, it was noted that the dead-weight towed body was prone to pitching, especially at reduced speeds. The instability of the towed body compromised the quality of the data; consequently, hull mountable transducers were purchased for installation in *Surveyor* during a dry-dock prior to the 1993 season. Unfortunately, budget constraints caused the dry-dock to be canceled, necessitating the use of a towed body again.

In the early part of Leg I, the acoustic towed body, two transducers, and a TDR were lost. Funding level uncertainties had precluded the purchase of a complete replicate backup system. For the remainder of Leg I, only a backup 120 kHz split-beam transducer was available for use. For Leg II, a replacement dead-weight towed body and new 120 kHz and 200 kHz transducers were purchased. Unfortunately, the new 200 kHz transducer, which is useful for acoustic identification and subsequent separation of disparate signals, was not working properly. Thus, our ability to acoustically distinguish krill from salps was significantly reduced throughout the cruise. Although the biomass in this area is considered to be predominantly krill, truly accurate biomass estimates rely on acoustic distinction of species. This was especially true this year as salps were found to be a significant component of samples collected during net tows. Also, the original dead-weight towed body was modified to operate in a side-looking mode in order to sample the water column between towing depth and the surface. Surveying this depth may be extremely important in quantitative acoustic surveys as krill are well known to migrate into this zone, especially during darkness. The loss of the towed-body also halted this study, which was scheduled to be conducted during Leg I.

Prior to the cruise, only the two transducers which were mounted inside the first dead-weight towed body were calibrated. Therefore, biomass estimates must await a post-cruise calibration of both the v-fin towed body system used during Leg I and the replacement dead-weight towed body system used during Leg II.

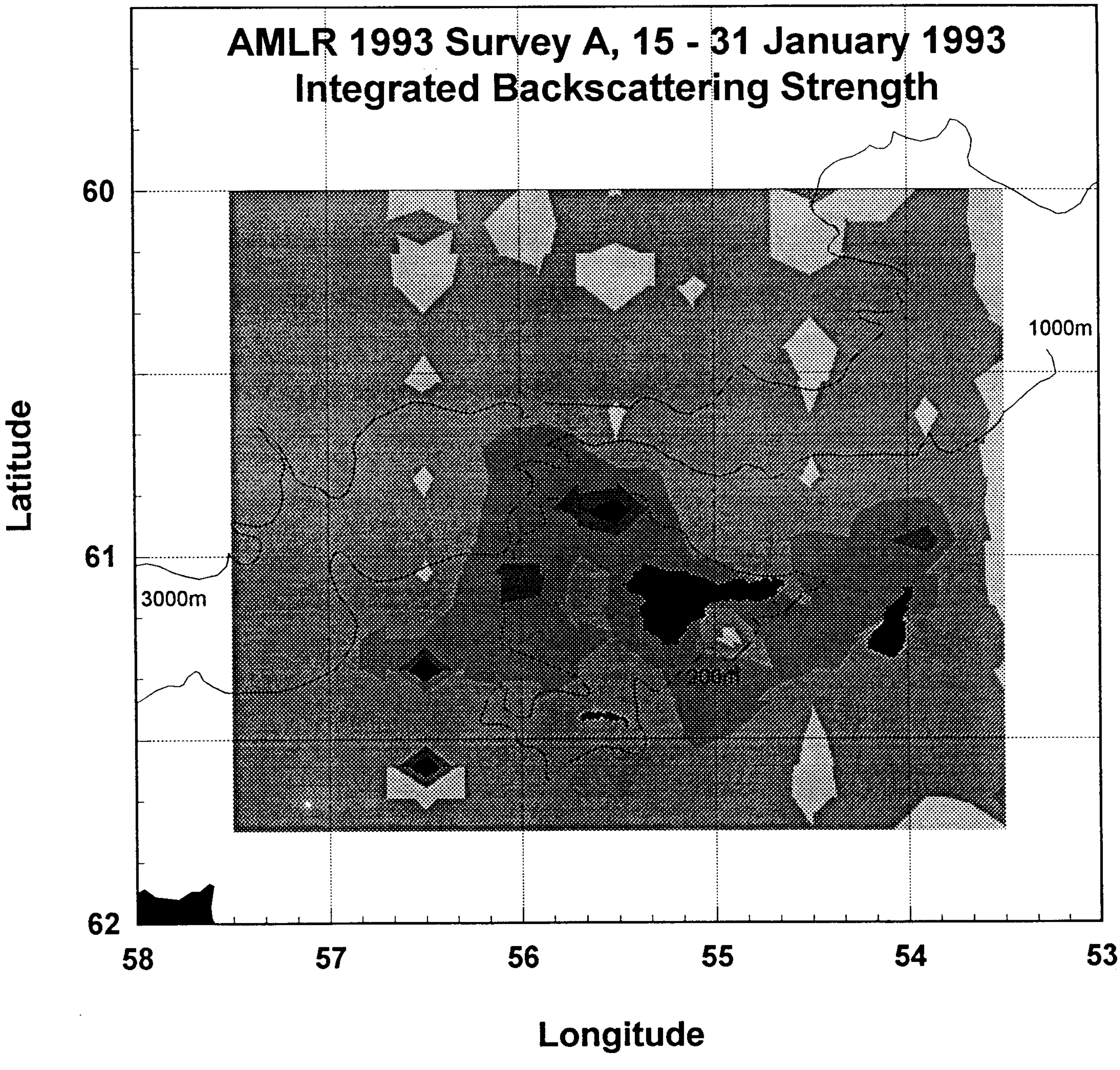


Figure 3.1 Integrated backscattering strength per n.mi.^{2} of sea surface area (proportional to krill density) for Survey A. Darker shading indicates higher krill density.

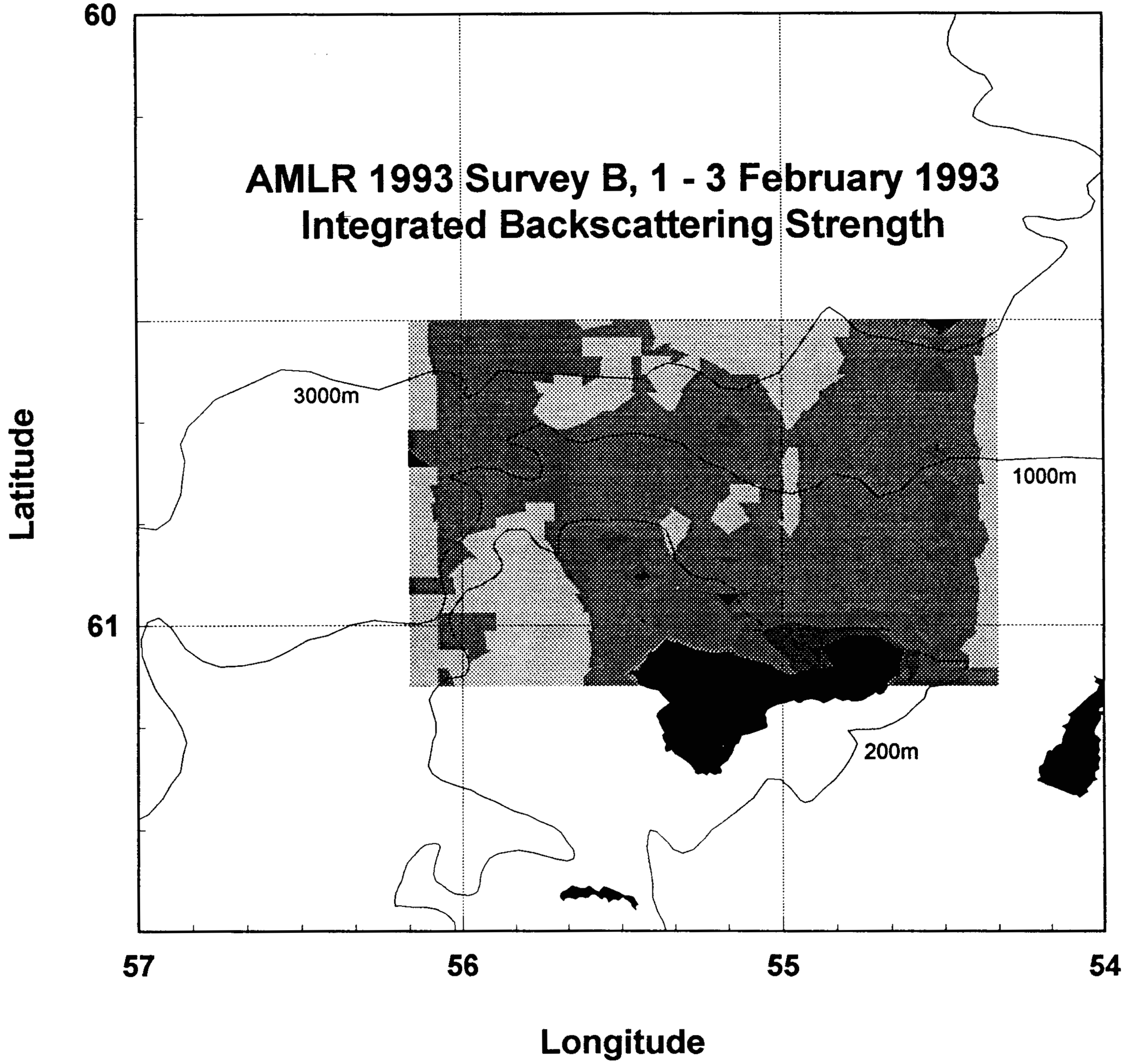


Figure 3.2 Integrated backscattering strength per n.mi.^{2} of sea surface area (proportional to krill density) for Survey B. Darker shading indicates higher krill density.

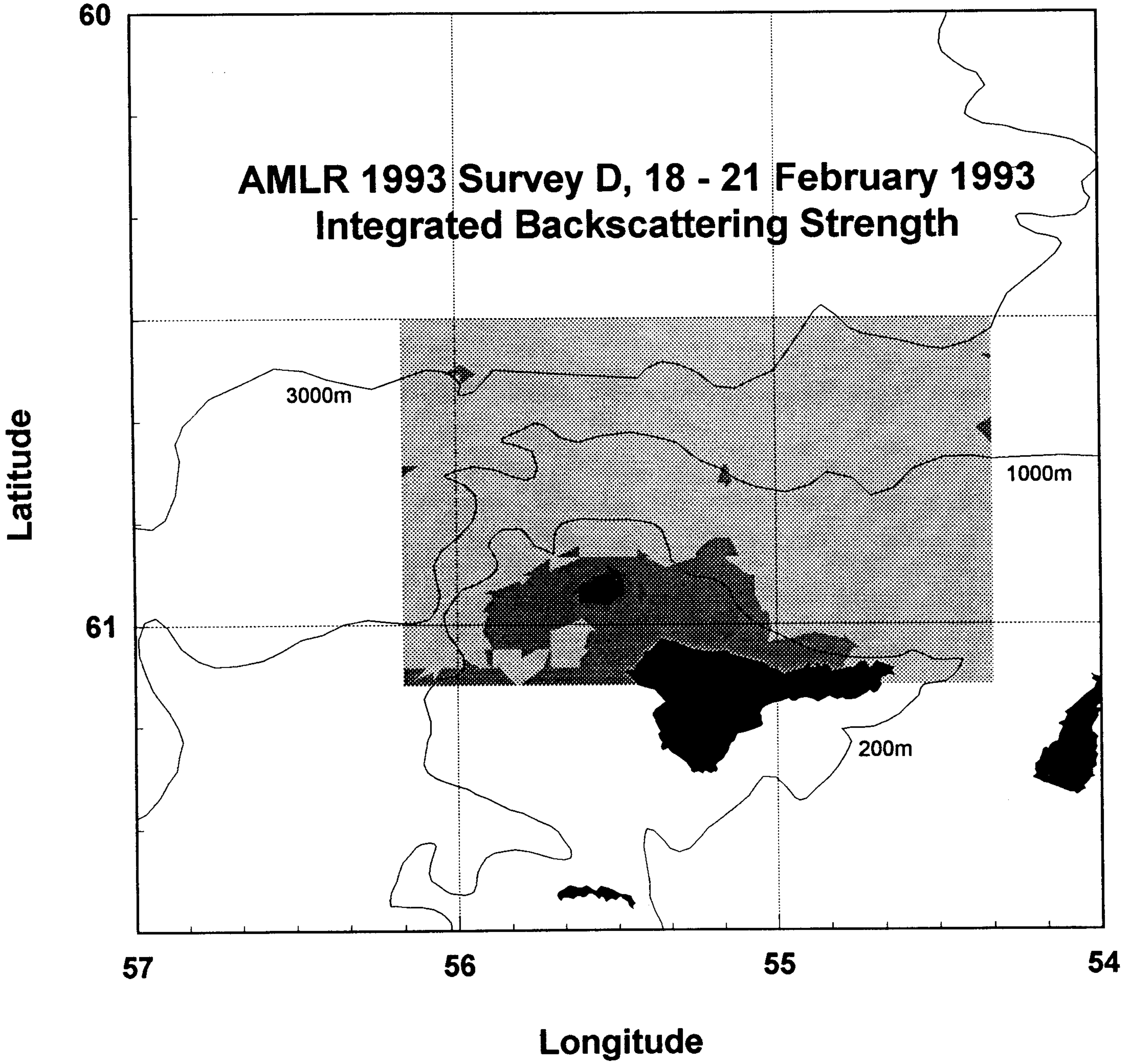


Figure 3.3 Integrated backscattering strength per n.mi.^{2} of sea surface area (proportional to krill density) for Survey D. Darker shading indicates higher krill density.

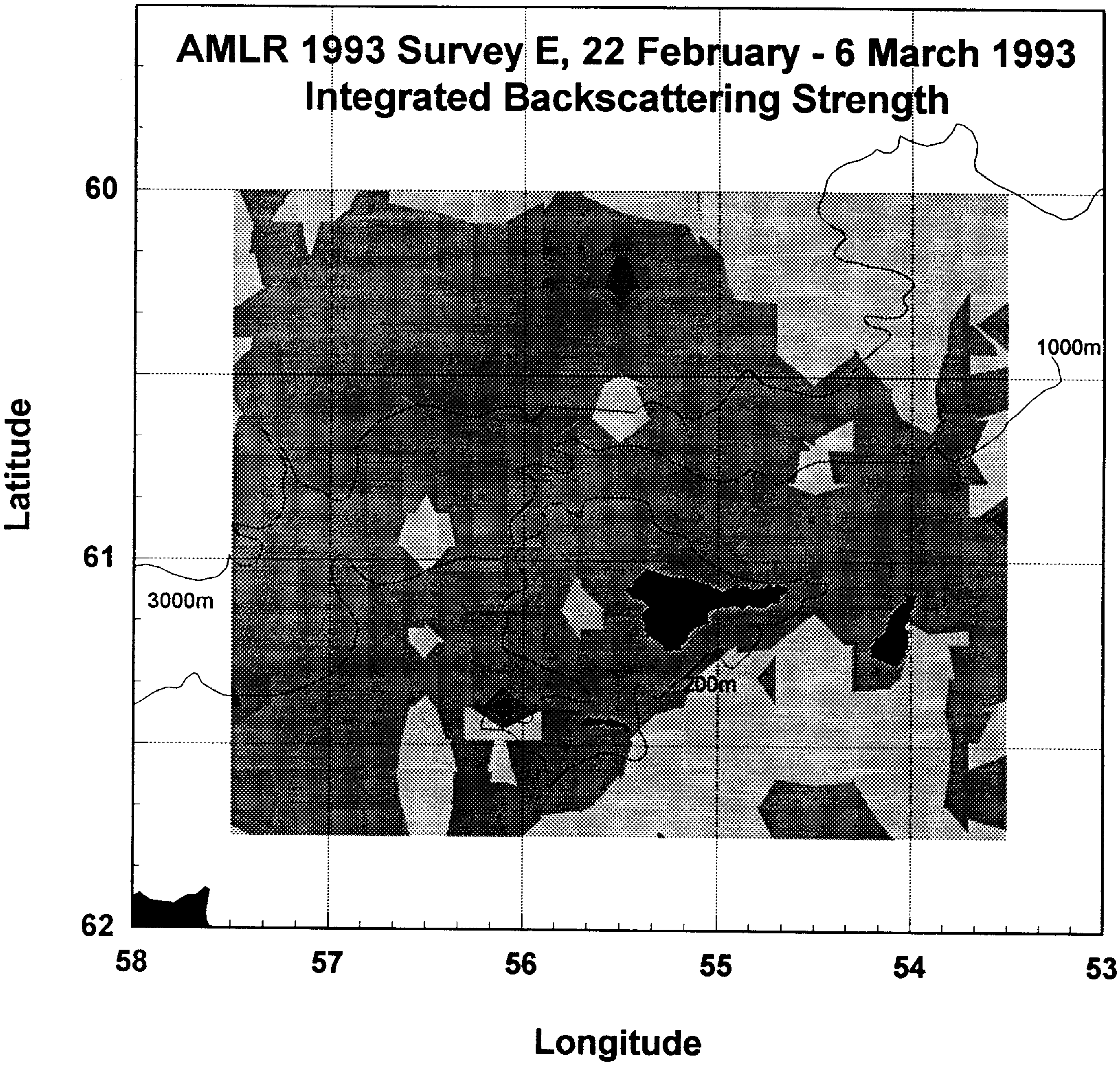


Figure 3.4 Integrated backscattering strength per n.mi.^{2} of sea surface area (proportional to krill density) for Survey E. Darker shading indicates higher krill density.

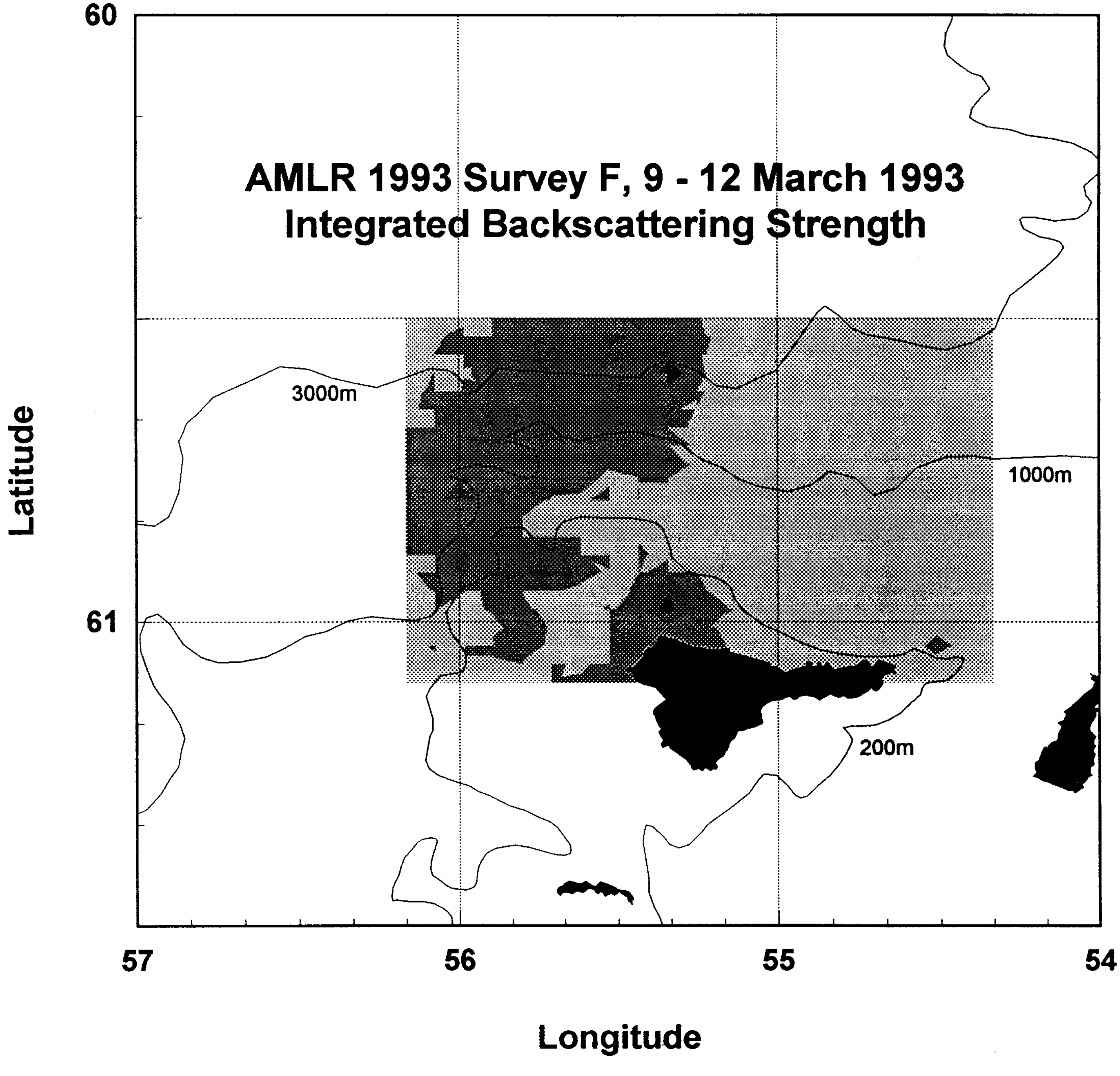


Figure 3.5 Integrated backscattering strength per n.mi.^{2} of sea surface area (proportional to krill density) for Survey F. Darker shading indicates higher krill density.

4. Direct krill and zooplankton sampling (IKMT net); submitted by Valerie Loeb (Legs I and II), Volker Siegel (Leg I), Renzo Follegati (Leg I), Sue Kruse (Leg II), Ned Laman (Legs I and II), David Low (Leg II), Luis Rodriguez (Leg II) and George Watters (Leg I).

4.1 Objectives: The objective of this work was to provide information on the demographic structure of krill (*Euphausia superba*) and the distribution of macrozooplankton components in the AMLR study area. Essential demographic information for krill includes length, sex ratio, reproductive condition, and maturity stages. Information useful for determining the relationship between krill distribution and population structure and ambient environmental conditions was derived from net samples taken at the established CTD/rosette stations within the large-area surveys. Ancillary information on the abundance and distribution of other macrozooplankton components was also obtained from the large-area survey samples.

4.2 Accomplishments: Krill and zooplankton were obtained from a 6' Isaacs-Kidd Midwater Trawl (IKMT) fitted with a 505μm mesh plankton net. Flow volumes were measured using a calibrated General Oceanics flowmeter mounted on the frame in front of the net mouth opening. All tows were fished obliquely to a depth of approximately 180m or to about 20m above bottom in shallower waters. Tow depths were derived from a Wildlife Corp. electronic depth recorder. A total of 88 non-targeted hauls were made during the first large-area survey (Survey A), 15 - 31 January (Table 4.1a). Two hauls were made at one station (tows 35a and b) as a result of a break in the sampling regime due to the loss of the acoustic towed body. Data from 87 tows (excluding A35b) are used in the analyses presented here. Eighty hauls were made during the second large-area survey (Survey E), 21 February - 6 March (Table 4.1b). Additional targeted IKMT and Multiple Opening Closing Net Environmental Sensing System (MOCNESS) tows were conducted during both cruise legs to provide the acoustics program with information on the relative abundance, size, and taxonomic composition of organisms within the upper 60m. This information is used for acoustic target identification and target strength calibration. Four MOCNESS tows were made during Leg I's first small-area survey (Survey B). During Leg II's small-area surveys, 1 MOCNESS and five IKMT tows were made during Survey D and 4 MOCNESS tows were made during Survey F.

Shipboard Analyses: Krill collected by the IKMT net tows were examined on board to provide information on the relative abundance and composition of stocks encountered during the large-area surveys. All krill were removed and counted from samples with <2,000 individuals; abundance estimates for larger samples (e.g., >2 liters of krill) were based on the numbers of individuals in three replicate 500ml aliquots. All samples of <150 individuals were completely analyzed. For larger samples, a minimum of 140 individuals were measured, sexed, and staged if only one size mode was present; at least 200 individuals were examined if two size modes were present. Measurements were made of total length; stages were based on the classification scheme of Makarov and Denys (1981). Zooplankton samples of <1 liter were saved in their entirety; 1 liter subsamples were made of larger samples. These were preserved in 10% formalin for subsequent onboard analysis of the larger zooplankton constituents. During Survey E, length measurements were made of representative subsamples of ca. 50 salps from each of 23 station samples. Abundance estimates of krill and zooplankton are expressed here as numbers per m^2 and/or numbers per 1000 m^3. Data are presented for the large-area surveys and for the more restricted "Elephant Island Area" (a box around Elephant Island; 60-62°S, 53-57°30'W) to allow comparison with previous AMLR cruises. Information on krill abundance and size frequency distributions and the relative abundance of other zooplankton components was derived from the targeted IKMT and MOCNESS tows and presented to acoustics program personnel during each cruise leg.

4.3 Results & preliminary conclusions:

Leg I, Survey A.

Krill: Seventy-nine of the 87 tows (91%) yielded approximately 22,100 krill; 5,135 of these were measured, sexed, and staged. Abundances in these tows ranged from 1 to about 11,500 krill. The overall estimated mean abundance was $8.0m^{-2}$ (± 28.2); the median value was $1.6m^{-2}$ (Table 4.1a). The catch sizes showed no obvious spatial pattern other than that the larger catches were relatively frequent in the area northeast of King George Island, while small catches were generally characteristic of the area south of Elephant Island (Figure 4.1). Greatest abundance ($250m^{-2}$) was at station A10 north of King George Island; another relatively large catch ($72m^{-2}$) was made at station A75 offshore to the northeast of Elephant Island.

The krill were dominated by reproductively mature (66%) and immature (29%) stages; juveniles made up only 5% of the total (Table 4.2). This maturity stage composition is reflected in the overall length frequency distribution which shows dominance by 35-50mm size classes and a paucity of individuals <30mm (Figure 4.2a). Also notable is the paucity of individuals >50mm. Females and males were equally represented (Table 4.2). Only 48% of the males were mature in contrast to 89% of the females. The majority of the females (73%) were stages 3a and 3b; few demonstrated advanced ovarian development (stage 3c, 14%) or were gravid (stage 3d, 2%). However, the maturity stage composition changed over time with a progression to more advanced female stages (i.e., greater incidence of gravid individuals) over the 16 day sampling period.

Both size and maturity stage composition varied over the survey area as indicated by a cluster analysis applied to the length frequency distributions from all stations represented by >20 krill. This analysis resulted in three clusters (Figures 4.2b and 4.3). Cluster 1 was composed primarily of immature (59%) and juvenile (23%) krill of 31-41mm length (35mm mode); males and females were fairly evenly represented (40% and 36%, respectively). These individuals represent the 2+ age group (i.e., 1990-91 year class) that was a dominant component in last year's catch. Cluster 3 was composed primarily of 41-51mm (47-48mm mode) mature krill (86%) with more males than females (63% vs.

37%). Cluster 2 included primarily mature krill (70%) of intermediate sizes (38-47mm, 41-42mm mode) and probably represents a mixture of individuals from clusters 1 and 3. Cluster 1 krill were distributed in Bransfield Strait waters to the south of King George and Elephant Islands and in the area between the two islands (Figure 4.4). Cluster 3 krill were primarily distributed in Drake Passage waters to the north of the two islands; they were also found over the southern shelf of King George Island and between Elephant and Clarence Islands. Cluster 2 occurred between the two other clusters and was most broadly distributed in the area northeast of Elephant Island.

Zooplankton: Zooplankton were sorted to the species level as far as possible. Forty-six species and taxonomic categories were identified (Table 4.3). Salps (*Salpa thompsoni*) were the overall dominant form and were present in all samples. The maximum catch was 47 liters with an estimated abundance of >16,000 salps per 1,000 m^3 (Table 4.4); the median catch was 2.5 liters and about 175 salps per 1,000 m^3. Largest salp concentrations occurred in the eastern portion of the study area (Figure 4.5). The euphausiid *Thysanoessa macrura* was the second most abundant species, present in 83 of the tows with a median abundance of 30 per 1,000 m^3. Krill was third in overall abundance. Larval fishes were rarely collected; the most abundant species were *Nototheniops larseni* and *Notolepis sp*. Cluster analysis applied to the zooplankton species composition and abundance yielded two groups of typically oceanic species, which differed only in the relative abundances of krill, copepods and *Euphausia frigida* (Table 4.3). There was no apparent pattern to the distribution of the two groups.

Leg II, Survey E.

Krill: Krill were collected by 68 of the 80 tows (85%) made during Survey E; 3,878 of these were measured, sexed and staged. The largest catch was about 3,660 krill, which was a third of the size of the largest catch of Survey A. The overall estimated mean abundance of $6.8m^{-2}$ (± 18.4) was similar to that of Leg I, but the median value of $0.3m^{-2}$ was about 20% of the Survey A value (Table 4.1b). As with Survey A, the catch sizes showed no obvious spatial pattern (Figure 4.6). Greatest abundance ($108m^{-2}$) was at station E52 southwest of Elephant Island. The diminished sampling effort in the King George Island area is a consequence of heavy weather conditions encountered during the last days of the survey effort.

Immature stages represented a much greater proportion of the krill than during Survey A (56% vs 29%; Table 4.2). Mature forms were relatively less abundant (41%), and juveniles continued to make up a small portion of the total (4%). Females and males were fairly equally represented. About 65% of the males were immature. Among the females, 50% were immature (stage 2), and 26% were mature but without attached spermatophores (stage 3a). This shift in maturity stage composition is reflected in the overall length frequency curve (Figure 4.7a), which shows significantly greater proportions of krill <40mm than during Survey A (Kolmogorov-Smirnov test, $P<0.01$).

Cluster analysis applied to the length frequency data yielded two groups (Figures 4.7b and 4.8). Cluster 1 was composed primarily of immature (67%) krill of 35-44mm length (37-40mm mode); females slightly outnumbered males (52% vs. 44%). Cluster 1 represents the 2+ age group. Cluster 2 resembles cluster 3 of Survey A in that it was composed primarily of 44-51mm (48-49mm mode) mature krill (94%). Males comprised about 75% of the individuals, and most of the females were in early stages of ovarian development (71% stages 3b,c). Cluster 1 krill were broadly distributed across most of the survey area, while the large, reproductively mature krill of cluster 2 were largely confined to the northernmost stations in Drake Passage (Figure 4.9). Males comprised over 70% of the individuals. Almost half of the females showed ovarian development or were gravid (stages 3c,d); at least 5% had recently spawned (Figure 4.8).

Zooplankton: Twenty-seven zooplankton species and taxonomic categories were identified from the Survey E samples (Table 4.3). Salps again were the overall dominant form and were present in all samples. The maximum catch was 92 liters with an estimated abundance of >16,000 salps per 1,000 m^3 (Table 4.4b). The median salp volume of 5.5 liters was 2X that of Survey A; the median abundance of about 700 salps per 1,000 m^3 was 4X that of Survey A. The lengths of 1,100 salps ranged from 3-150mm, with a mean of 48mm (±25mm). Large salp concentrations (1,000 - 10,000 per 1,000 m^3) occurred over most of the survey area (Figure 4.10). Lowest concentrations occurred around and to the northwest of Elephant Island. *Thysanoessa macrura* remained the second most abundant species, present in 77 of the tows with a median abundance (29 per 1,000 m^3) similar to that during Survey A. Krill was third in overall abundance. Among the other zooplankton taxa, only the amphipods *Themisto gaudichaudii* and *Cyllopus spp.* appeared to have increased abundances during Survey E relative to Survey A (Table 4.3).

"Elephant Island Area" and between year comparisons: During January 1993, the salp abundance within the Elephant Island area was an order of magnitude greater and krill abundance about 2X greater than during January 1992; abundance of *Thysanoessa macrura* was similar between the two years (Table 4.4). During February-March 1993, the median krill abundance was less than half that during the corresponding period in 1992. It is conceivable that the decreased krill abundance with advancing season was related to the increasing abundance of (and competition by) salps in the Elephant Island area. The coincidental change in krill length frequency distribution and maturity stage composition and shift in the location of large sized krill suggests that (a) the more nektonic individuals were actively avoiding the area and/or (b) physical processes mediating their presence and concentration in the area were weak or absent.

The overall krill length frequency distributions and maturity stage composition during the two large-area surveys differed substantially from that observed the previous year (Table 4.2). The greatest difference this year is the absence of a distinct juvenile mode around 28mm and the presence of intermediate sized mode around 35mm. The paucity of small juveniles suggests poor spawning and/or larval survival during the previous (i.e., 1991/92) season. The relatively abundant intermediate sized krill of 31-41mm, which represent the 2+ age group, reflect the apparent success of the 1990/91 year class. The low numbers of krill >50mm has to be examined in more detail by analyzing the long term data set.

4.4 Disposition of data and samples: All of the krill demography data and large zooplankton data have been digitized and are available upon request from Loeb and Siegel. The krill and subsamples of zooplankton will be sent to the Southwest Fisheries Science Center for storage. The zooplankton, minus salps and larval fish, were placed in vials and included with the krill fraction from each tow. The larval fishes will be sent to Moss Landing Marine Laboratories (Loeb) for further analysis and inclusion in the long term AMLR ichthyoplankton collection and database. Myctophids collected by the IKMT have been preserved in alcohol and will be sent to the Southwest Fisheries Science Center (George Watters).

4.5 Problems and suggestions: The electronic time depth recorders used this year appeared to have worked well; three separate calibrations with the CTD verified their accuracy. However, because the trawl winch metering device was defective, difficulties were encountered in achieving desired sampling depths; benthic trawls occurred twice in waters <200m. These difficulties were eliminated during Leg II after the defect was identified and repaired. We highly recommend that the winch metering device be calibrated prior to net sampling activities during each leg. Also, a continuously monitored deck-readout of the sampling depth would be exceedingly useful.

Shipboard analysis proved to be an effective way of assessing krill and larger zooplankton distributional patterns relative to hydrographic conditions in a more or less real-time manner and should be continued. However, we were understaffed for this task, especially given this year's elevated abundance of salps and krill, the numbers of stations sampled over the 24 hour a day periods, and the increased sampling frequency with the new acoustics towed body. A realistic team would include 4 people (two per watch) to conduct tows and gross sample processing, and at least two, or preferably three, experienced people to conduct krill and zooplankton analyses. During Leg II, it became obvious that an explicit processing protocol for samples must be developed to permit a consistent zooplankton database.

TABLE 4.1 AMLR 1993 Large area survey IKMT station information.

A. SURVEY A

STATION #	DATE	START TIME	END TIME	DIEL	TOW DEPTH(m)	BOTTOM DEPTH(m)	VOLUME (m3)	KRILL: TOTAL	#/M2	#/1000M3
A01	15/01/93	1600	1635	D	140	1335	6054	40	0.9	6.6
A03	15/01/93	2237	2307	T	205	310	5657	0	0.0	0.0
A04	16/01/93	0218	0253	T	255	1421	6501	3	0.1	0.5
A05	16/01/93	0640	0713	D	250	1849	5502	75	3.4	13.6
A06	16/01/93	0940	1013	D	180	1400	7043	26	0.7	3.7
A07	16/01/93	1308	1345	D	280	1985	7334	9	0.3	1.2
A09	16/01/93	2030	2052	D	200	282	3832	0	0.0	0.0
A10	16/01/93	2325	2356	T	154	888	7084	11500	250.0	1623.4
A11	17/01/93	0250	0314	T	80	1001	5460	185	2.7	33.9
A12	17/01/93	0653	0720	D	206	1071	4758	101	4.4	21.2
A13	17/01/93	1001	1027	D	202	290	5542	0	0.0	0.0
A14	17/01/93	1328	1340	D	68	150	2485	2	0.1	0.8
A15	17/01/93	1611	1635	D	192	330	4633	32	1.3	6.9
A16	17/01/93	1917	1945	D	200	675	5420	96	3.5	17.7
A17	18/01/93	0136	0209	T	244	380	6621	119	4.4	18.0
A18	18/01/03	0504	0535	D	260	471	6392	337	13.7	52.7
A19	18/01/93	0828	0851	D	172	2700	4881	34	1.2	7.0
A20	18/01/93	1117	1153	D	252	2000	7465	21	0.7	2.8
A21	18/01/93	1424	1452	D	226	4500	5574	121	4.9	21.7
A22	18/01/93	1723	1750	D	202	3704	5404	21	0.8	3.9
A23	18/01/93	2021	2043	D	238	2500	4859	31	1.5	6.4
A24	18/01/93	2312	2334	T	212	1500	4731	1	0.0	0.2
A25	19/01/93	0230	0256	D	180	1320	5556	14	0.5	2.5
A26	19/01/93	0609	0637	D	190	1370	6039	77	2.4	12.7
A27	19/01/93	0941	1004	D	190	1500	4594	326	13.5	71.0
A28	19/01/93	1303	1329	D	240	1384	4700	49	2.5	10.4
A29	19/01/93	1649	1714	D	254	2831	4312	52	3.1	12.1
A30	19/01/93	2011	2035	D	214	1740	4684	79	3.6	16.9
A31	19/01/93	2345	0010	T	190	480	4608	59	2.4	12.8
A32	20/01/93	0257	0322	T	278	416	4730	342	20.1	72.3
A33	20/01/93	0609	0632	D	200	630	3428	18	1.1	5.3
A34	20/01/93	0932	0953	D	206	1600	4168	3	0.1	0.7
A35a	20/01/93	1300	1324	D	200	1842	4497	332	14.8	73.8
A35b	21/01/93	2024	2046	D	200	1730	3853	135	7.0	35.0
A36	22/01/93	0115	0141	T	206	544	4832	903	38.5	186.9
A37	22/01/93	0640	0706	D	214	524	5096	122	5.1	23.9
A38	22/01/93	1151	1217	D	214	390	5261	239	9.7	45.4
A39	22/01/93	1626	1652	D	200	2080	4345	14	0.6	3.2
A40	22/01/93	2107	2131	D	230	3950	4534	65	3.3	14.3
A41	23/01/93	0134	0203	T	248	3959	4645	659	35.2	141.9
A42	23/01/93	0529	0557	D	260	3900	4937	10	0.5	2.0
A43	23/01/93	0920	0942	D	260	3610	4195	44	2.7	10.5
A44	23/01/93	1344	1409	D	232	3718	4650	25	1.2	5.4
A45	23/01/93	1752	1824	D	258	3800	5001	44	2.3	8.8
A46	23/01/93	2249	2323	T	170	3900	7878	0	0.0	0.0
A47	24/01/93	0342	0411	T	242	3792	4299	1	0.1	0.2
A48	24/01/93	0829	0850	D	232	920	4277	178	9.7	41.6
A49	24/01/93	1255	1304	D	64	171	1868	13	0.4	7.0
A50	24/01/93	1640	1705	D	148	360	4826	938	28.8	194.4
A51	24/01/93	2122	2148	D	248	780	4629	0	0.0	0.0
A52	25/01/93	0144	0211	T	214	1788	4983	3	0.1	0.6

TABLE 4.1 AMLR 1993 Large area survey IKMT station information.

STATION #	DATE	START TIME	END TIME	DIEL	TOW DEPTH(m)	BOTTOM DEPTH(m)	VOLUME (m3)	KRILL: TOTAL	#/M2	#/1000M3
A54	25/01/93	0910	0916	D	32		1002	0	0.0	0.0
A55	25/01/93	1317	1323	D	22	50	1091	0	0.0	0.0
A56	25/01/93	1731	1803	D	220	3530	6044	36	1.3	6.0
A57	25/01/93	2121	2145	D	216	3650	4283	32	1.6	7.5
A58	26/01/93	0130	0157	N	266	3581	4336	473	29.0	109.1
A59	26/01/93	0536	0714	D	182	3555	18567	5	0.0	0.3
A60	26/01/93	1035	1103	D	236	3000	4539	57	3.0	12.6
A61	26/01/93	1424	1450	D	212	3392	4934	20	0.9	4.1
A62	26/01/93	1818	1845	D	210	3445	4999	78	3.3	15.6
A63	26/01/93	2022	2045	T	172	3200	4749	80	2.9	16.8
A64	27/01/93	0228	0253	N	172	526	4884	383	13.5	78.4
A66	27/01/93	1350	1415	D	252	938	4609	4	0.2	0.9
A67	27/01/93	1742	1815	D	184	2040	5689	7	0.2	1.2
A68	27/01/93	2111	2131	D	164	780	4980	2	0.1	0.4
A69	28/01/93	0127	0154	N	238	1537	4826	9	0.4	1.9
A70	28/01/93	0524	0551	D	218	500	4472	41	2.0	9.2
A71	28/01/93	0819	0844	D	220	600	4354	554	28.0	127.2
A72	28/01/93	1211	1234	D	220	3018	4299	55	2.8	12.8
A73	28/01/93	1525	1551	D	166	3282	5645	31	0.9	5.5
A74	28/01/93	1858	1930	D	216	3085	5431	41	1.6	7.5
A75	28/01/93	2315	0010	N	164	3211	4776	2096	72.0	438.9
A76	29/01/93	0418	0444	T	202	3032	4749	6	0.3	1.3
A77	29/01/93	0846	0908	D	184	2800	4287	79	3.4	18.4
A78	29/01/93	1217	1243	D	172	3029	4682	74	2.7	15.8
A79	29/01/93	1550	1621	D	200	1800	5175	76	2.9	14.7
A80	29/01/93	1946	2013	D	170	1020	4778	1	0.0	0.2
A81	29/01/93	2356	0025	N	282	1250	3996	22	1.6	5.5
A82	30/01/93	0439	0507	D	190	780	5371	3	0.1	0.6
A83	30/01/93	0807	0827	D	202	350	3590	1	0.1	0.3
A84	30/01/93	1234	1252	D	190	559	3963	0	0.0	0.0
A85	30/01/93	1600	1624	D	172	700	4396	26	1.0	5.9
A86	30/01/93	1947	2010	D	194	1050	4712	183	7.5	38.8
A87	30/01/93	2349	0017	N	210	1988	4364	1	0.0	0.2
A88	31/01/93	0354	0421	T	216	575	4624	18	0.8	3.9
A89	31/01/93	0727	0757	D	212	2620	5125	110	4.5	21.5
A90	31/01/93	1114	1147	D	236	2480	4215	75	4.2	17.8
A91	31/01/93	1445	1505	D	140	3309	4796	62	1.8	12.9

SURVEY A					
A01-A91	NO.	N = 88	22239		
	MEAN			7.9	43.9
	STD			28.0	179.0
	MEDIAN			1.6	7.2
LESS A35b	NO.	N = 87	22104		
	MEAN			8.0	44.1
	STD			28.2	180.0
	MEDIAN			1.6	7.0
ELEPHANT ISLAND AREA	NO.	N = 70	9682		
	MEAN			5.8	28.9
	STD			11.6	63.8
	MEDIAN			1.7	8.2

TABLE 4.1 AMLR 1993 Large area survey IKMT station information.

B. SURVEY E

STATION #	DATE	START TIME	END TIME	DIEL	TOW DEPTH(m)	BOTTOM DEPTH(m)	VOLUME (m3)	KRILL: TOTAL	#/M2	#/1000M3
E01	06/03/93	0257	0327	N	198	1554	5613	43	1.5	7.7
E02	05/03/93	2355	0027	N	188	1685	5271	2150	76.7	407.9
E03	05/03/93	2125	2140	N	30	65	3080	0	0.0	0.0
E04	05/03/93	1834	1907	D	172	1622	5941	1	0.0	0.2
E05	05/03/93	1515	1546	D	220	1830	5544	0	0.0	0.0
E06	05/03/93	1217	1251	D	200	1585	6246	0	0.0	0.0
E07	05/03/93	0858	0938	D	178	1985	6560	1	0.0	0.2
E08	05/03/93	0606	0641	T	172	295	5682	5	0.2	0.9
E13	04/03/93	1217	1241	D	116	288	5010	1	0.0	0.2
E14	04/03/93	0853	0906	D	72	150	2143	0	0.0	0.0
E17	03/03/93	1954	2021	T	166	374	3894	0	0.0	0.0
E19	03/03/93	1306	1330	D	222	2680	3225	158	10.9	49.0
E20	03/03/93	0955	1029	D	180	4100	6206	3	0.1	0.5
E21	03/03/93	0650	0727	D	184	2700	6704	512	14.1	76.4
E24	02/03/93	2133	2202	N	176	1620	5658	115	3.6	20.3
E25	02/03/93	1834	1900	D	174	1340	3667	4	0.2	1.1
E26	02/03/93	1516	1548	D	150	1940	5947	10	0.3	1.7
E27	02/03/93	1214	1239	D	204	2055	3604	52	2.9	14.4
E28	02/03/93	0900	0937	D	166	3690	7042	6	0.1	0.9
E29	02/03/93	0521	0559	T	238	2855	4668	1	0.1	0.2
E30	02/03/93	0139	0212	N	204	1788	4837	43	1.8	8.9
E31	01/03/93	1932	2005	D	180	485	4460	1	0.0	0.2
E32	01/03/93	1623	1650	D	172		4347	2	0.1	0.5
E33	01/03/93	1338	1408	D	160	527	5286	0	0.0	0.0
E34	01/03/93	1008	1041	D	228	1530	4757	1	0.0	0.2
E35	01/03/93	0558	0631	T	238	1750	4956	1	0.0	0.2
E36	01/03/93	0223	0258	N	174	548	5242	207	6.9	39.5
E37	28/02/93	2327	0000	N	166	500	5738	817	23.6	142.4
E38	28/02/93	2050	2113	T	174	336	5698	77	2.4	13.5
E39	28/02/93	1802	1831	D	148	2128	4623	1	0.0	0.2
E40	28/02/93	1507	1533	D	156	2619	4559	2	0.1	0.4
E41	28/02/93	1147	1217	D	216	3940	4532	3	0.1	0.7
E42	28/02/93	0840	0916	D	168	3880	5671	41	1.2	7.2
E43	28/02/93	0525	0600	T	174	3632	6134	149	4.2	24.3
E44	28/02/93	0205	0238	N	180	3723	5186	360	12.5	69.4
E45	27/02'93	2306	2336	N	220	3815	4055	64	3.5	15.8
E46	27/02/93	2015	2046	T	170	3900	4468	5	0.2	1.1
E47	27/02/93	1611	1642	D	176	2788	4778	125	4.6	26.2
E48	27/02/93	1324	1357	D	146	480	6373	186	4.3	29.2
E49	27/02/93	1007	1032	D	160	160	3634	0	0.0	0.0
E50	27/02/93	0700	0740	D	200	383	5884	8	0.3	1.4
E51	27/02/93	0339	0417	D	180	800	6766	2090	55.6	308.9
E52	27/02/93	0026	0105	N	200	2090	6753	3660	108.4	542.0
E53	26/02/93	2109	2139	N	178	515	4250	7	0.3	1.6
E54	26/02/93	1835	1853	D	68	60	2787	2	0.0	0.7
E55	26/02/93	1540	1552	D	50	70	2001	0	0.0	0.0
E56	26/02/93	1242	1314	D	184	3248	5304	11	0.4	2.1
E57	26/02/93	0945	1021	D	188	3630	6036	33	1.0	5.5
E58	26/02/93	0633	0711	D	214	3500	5935	0	0.0	0.0
E59	26/02/93	0325	0357	N	142	3582	5597	17	0.4	3.0

TABLE 4.1 AMLR 1993 Large area survey IKMT station information.

STATION #	DATE	START TIME	END TIME	DIEL	TOW DEPTH(m)	BOTTOM DEPTH(m)	VOLUME (m3)	KRILL:	TOTAL	#/M2	#/1000M3
E60	26/02/93	0015	0038	N	184	3583	3310		1165	64.8	352.0
E61	25/02/93	2058	2126	N	154	3385	4371		0	0.0	0.0
E62	25/02/93	1724	1757	D	162	3240	4975		1	0.0	0.2
E63	25/02/93	1414	1437	D	204	3258	3424		10	0.6	2.9
E64	25/02/93	1117	1128	D	68	240	1615		1	0.0	0.6
E65	25/02/93	0630	0652	T	102	215	3929		0	0.0	0.0
E66	25/02/93	0324	0351	N	170	650	4387		28	1.1	6.4
E67	25/02/93	0009	0034	N	204	2050	4047		1	0.1	0.2
E68	24/02/93	2104	2136	N	230	585	4998		206	9.5	41.2
E69	24/02/93	1752	1830	D	172	1600	2189		3	0.2	1.4
E70	24/02/93	1454	1527	D	172	486	5532		2	0.1	0.4
E71	24/02/93	1137	1204	D	180	600	3897		68	3.1	17.5
E72	24/02/93	0838	0913	D	128	2780	7305		4	0.1	0.5
E73	24/02/93	0540	0607	T	150	3220	4760		144	4.5	30.3
E74	24/02/93	0234	0300	N	220	3060	4706		95	4.4	20.2
E75	23/02/93	2316	2346	N	154	3200	4358		36	1.3	8.3
E76	23/02/93	2003	2029	D	110	3100	4648		0	0.0	0.0
E77	23/02/93	1651	1715	D	118	2755	4405		1	0.0	0.2
E78	23/02/93	1339	1402	D	258	3033	4014		12	0.8	3.0
E79	23/02/93	1021	1043	D	226	1585	4002		5	0.3	1.2
E80	23/02/93	0625	0720	D	185	1290	9958		563	10.5	56.5
E81	23/02/93	0318	0344	N	208	1293	4371		434	20.7	99.3
E82	22/02/93	2346	0013	N	252	980	4271		1045	61.7	244.7
E83	22/02/93	2000	2029	D	140	335	5842		0	0.0	0.0
E84	22/02/93	1624	1648	D	228	540	4173		7	0.4	1.7
E85	22/02/93	1325	1346	D	170	714	3853		36	1.6	9.3
E86	22/02/93	0924	0941	D	170	980	4388		156	6.0	35.5
E87	22/02/93	0620	0641	D	182	2090	4280		15	0.6	3.5
E88	22/02/93	0330	0355	N	237	600	4748		138	6.9	29.1
E91	21/02/93	1859	1930	D	172	3300	6185		25	0.7	4.0
SURVEY E						NO.	N = 80		15176		
						MEAN				6.7	34.5
						STD				18.3	92.9
						MEDIAN				0.3	1.5
ELEPHANT ISLAND AREA						NO.	N = 67		12973		
						MEAN				6.8	35.0
						STD				17.8	89.7
						MEDIAN				0.6	3.0

Table 4.2 Maturity stage composition of krill collected in the large survey areas and Elephant Island area during 1993 compared to the Elephant Island area during 1992.

	E. superba January			*E. superba* February-March		
Area	1993 Survey A	1993 Elephant I.	1992 Elephant I.	1993 Survey E	1993 Elephant I.	1992 Elephant I.
	%	%	%	%	%	%
Juveniles	5.2	7.2	37.1	3.6	3.5	33.6
Immature stages	29.2	30.7	19.1	55.8	51.4	27.1
Mature stages	65.6	62.2	44.1	40.6	45.1	39.2
Females:						
F2	5.4	7.8	0.8	23.2	21.8	0.8
F3a	20.4	11.7	0.6	12.1	12.4	10.3
F3b	16.1	14.3	12.3	5.6	6.2	10.2
F3c	7.0	5.1	9.2	3.2	3.7	4.3
F3d	0.6	1.2	0.4	1.0	1.1	1.2
F3e	0.0	0.0	0.0	1.1	1.2	<0.01
Males:						
M2a	5.8	6.8	8.7	6.9	6.9	Immature:
M2b	13.2	11.9	7.3	22.2	19.1	
M2c	4.7	4.2	2.3	3.5	3.6	26.4
M3a	3.9	3.7	2.8	1.8	2.1	Mature:
M3b	17.6	26.2	18.8	15.7	18.4	13.2
Male:Female ratio	0.9:1	1.3:1	1.7:1	1.1:1	1.1:1	1.5:1
No. measured	5135	4283	2472	3878	3669	3646

Table 4.3 Zooplankton taxa present in AMLR 1993 Survey A and Survey E samples. F is frequency of occurrence (%) in tows. Abundances are presented for the two survey areas and for two groupings derived from cluster analysis of species composition and abundance for survey A. n.a. indicates taxa present but not enumerated during survey E.

Taxon	Survey A				Survey E	
	F (87 tows)	Mean #/1000 m3	Cluster A Mean #/1000 m	Cluster B Mean #/1000 m	F (80 tows)	Mean #/1000 m
Salpa thompsoni	100.0	1001.5	994.4	1026.9	100.0	1567.1
Thysanoessa macrura	95.4	51.5	44.1	76.1	96.3	141.5
Euphausia superba	90.8	44.1	55.5	3.0	83.8	35.0
Vibilia antarctica	64.4	1.6	1.5	1.7	47.5	1.6
Chaetognatha	56.3	9.2	3.1	31.3	n.a.	n.a.
Themisto gaudichaudii	50.6	0.8	0.9	0.4	60.0	2.3
Spongiobranchaea australis	40.2	0.6	0.6	0.6	20.0	0.3
Tomopteris carpenteri	33.3	0.5	0.6	0.2	12.5	0.2
Copepoda	31.0	38.1	2.0	167.4	n.a.	n.a.
Euphausia frigida	26.4	3.6	1.7	10.6	7.5	1.0
Euphausia triacantha	25.3	1.0	1.2	0.3	21.3	1.0
Diphyes antarctica	20.7	0.5	0.5	0.3	15.0	0.3
Cyllopus magellanicus	18.4	0.5	0.5	0.6	32.5	0.9
Nototheniops larseni (larvae)	16.1	0.2	0.1	0.7	5.0	0.2
Notolepis sp. (larvae)	12.6	0.1	0.0	0.0	3.8	0.1
Cyllopus lucasii	11.5	0.4	0.2	1.2	37.5	1.5
Electrona antarctica (adults)	10.3	0.0	0.0	0.0	3.8	0.0
Clio pyramidata	6.9	0.2	0.2	0.0	1.3	0.0
Hyperiella dilatata	6.9	0.0	0.0	0.0	1.3	0.0
Notothenia kempi (larvae)	5.7	0.1	0.1	0.0	1.3	0.0
Clione limacina	4.6	0.1	0.0	0.0	---	---
Periphylla periphylla	4.6	0.0	0.0	0.0	---	---
Vanadis antarctica	4.6	0.0	0.0	0.0	---	---
Dimophyes arctica	3.4	0.0	0.0	0.1	6.3	0.2
Orchomene plebs	3.4	0.1	0.0	0.0	---	---
Primno macropa	3.4	0.0	0.0	0.1	---	---
Electrona antarctica (larvae)	2.3	0.0	0.0	0.0	5.0	0.1
Beroe cucumis	2.3	0.0	0.0	0.0	1.3	0.0
Chionodraco rastrospinosus (larvae)	2.3	0.0	0.0	0.0	---	---
Eusirus microps	2.3	0.0	0.0	0.0	1.3	0.0
Hyperiella antarctica	2.3	0.0	0.0	0.0	---	---
Scyphomedusae sp. 1	2.3	0.0	0.0	0.0	1.3	0.0
Scyphomedusae sp. 4	2.3	0.0	0.0	0.0	---	---
Travisiopsis levinseni	2.3	0.0	0.0	0.0	---	---
Atolla wyvillei	1.1	0.0	0.0	0.0	---	---
Beroe forskalii	1.1	0.0	0.0	0.0	---	---
Calycopsis borchgrevinki	1.1	0.0	0.0	0.0	11.3	0.1
Chaenodraco wilsoni (larva)	1.1	0.0	0.0	0.0	---	---
Cyphocaris richardi	1.1	0.0	0.0	0.0	---	---
Decapoda sp. (larva)	1.1	0.0	0.0	0.0	---	---
Hyperia macrocephala	1.1	0.4	0.0	2.0	---	---
Hyperiella macronyx	1.1	0.0	0.0	0.0	---	---
Scyphomedusae sp. 2	1.1	0.0	0.0	0.0	---	---
Scyphomedusae sp. 3	1.1	0.0	0.0	0.0	---	---
Euphausia crystallorophias	1.1	0.0	0.0	0.0	5.0	0.2
Nototheniops nudifrons (larvae)	1.1	0.1	0.0	0.6	---	---
Nototheniops larseni (juv)			---	---	1.3	0.0
Pleuragramma antarcticum (juv)			---	---	2.5	0.0

Table 4.4A. Abundance of dominant zooplankton species collected in the Survey A area and in the Elephant Island area during January 1993 compared to January 1992. B. Abundance of these species in the Survey E area and Elephant Island area during February-March 1993 and of E. superba in the Elephant Island area during February-March 1992.

A.	*E. superba*			January *T. macrura*			Salps		
	1993	1993	1992	1993	1993	1992	1993	1993	1992
Area	Survey A	Elephant I.	Elephant I.	Survey A	Elephant I.	Elephant I.	Survey A	Elephant I.	Elephant I.
Median #/1000 m3	7.0	8.2	4.8	30.2	27.5	22.5	173.6	245.8	14.0
Mean #/1000 m3	44.0	28.8	19.9	51.1	48.6	48.1	1001.5	1213.4	94.3
Std. Dev.	181.0	64.4	65.5	60.8	60.1	57.0	2313.3	2536.7	192.3
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.9	6.9	0.0
Maximum	1623.4	438.9	495.2	307.1	307.1	233.7	16078.8	16078.8	1231.1
25% percentile	0.9	1.3	1.0	7.7	5.9	7.8	62.1	63.4	0.2
75% percentile	18.0	18.0	12.6	64.8	63.7	67.4	706.0	975.0	90.3

B.	*E. superba*			February-March *T. macrura*			Salps		
	1993	1993	1992	1993	1993		1993	1993	
Area	Survey E	Elephant I.	Elephant I.	Survey E	Elephant I.		Survey E	Elephant I.	
Median #/1000 m3	1.6	3.0	7.1	29.1	22.1		701.2	605.9	
Mean #/1000 m3	35.0	35.5	38.0	35.0	128.9		1567.1	1585.9	
Std. Dev.	93.4	90.2	77.4	93.4	235.1		2532.4	2725.5	
Minimum	0.0	0.0	0	0.0	0.0		2.2	2.2	
Maximum	542.0	542.0	389.9	1176.3	1141.5		16662.5	16662.5	

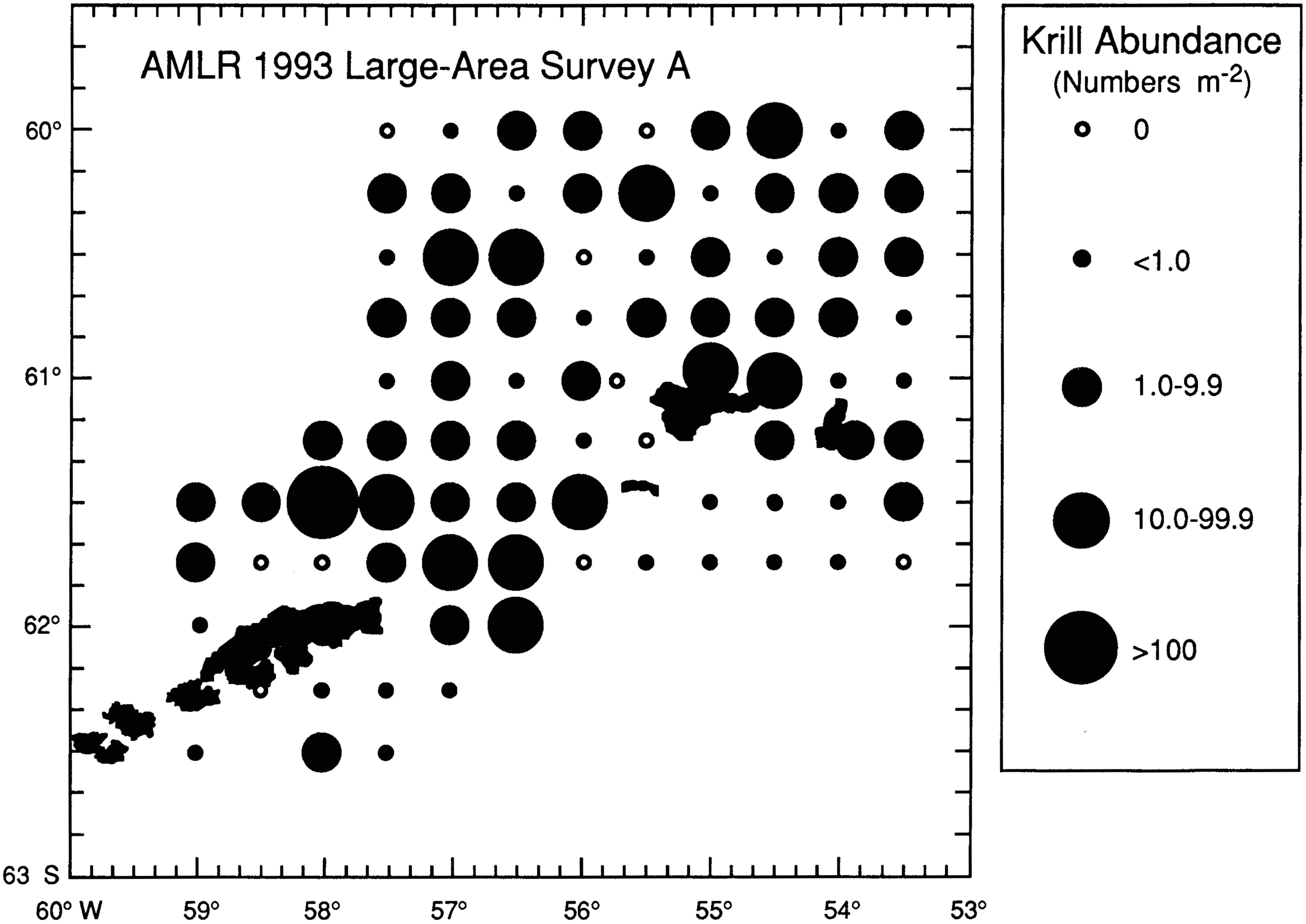


Figure 4.1 Krill abundance in IKMT tows collected during Survey A, January 1993.

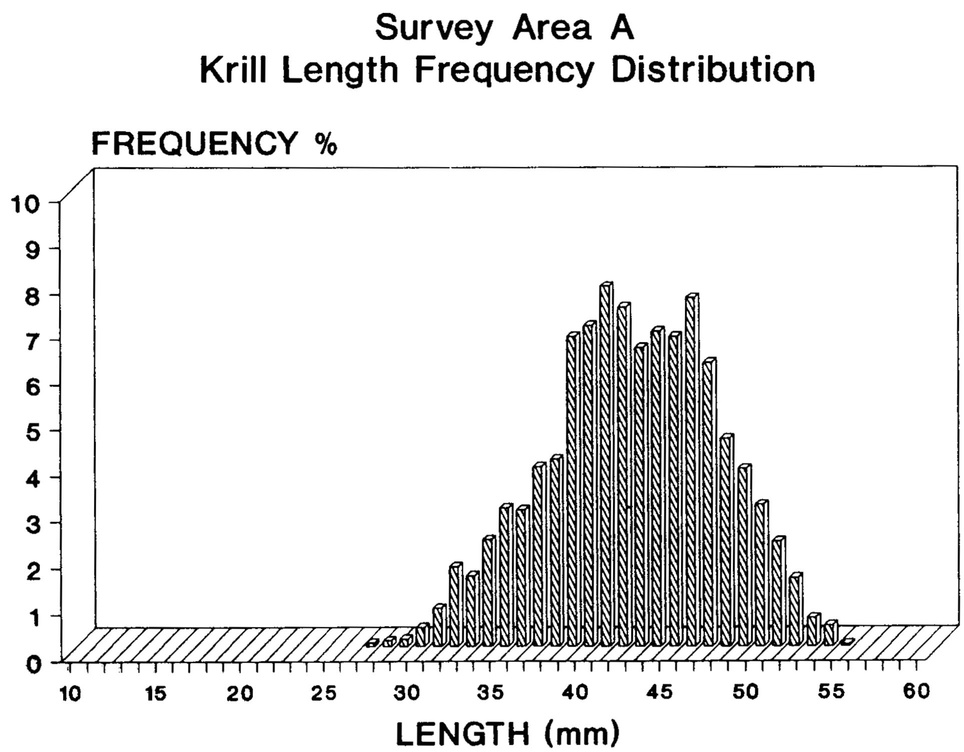


Figure 4.2a Overall length frequency distribution of krill collected during Survey A.

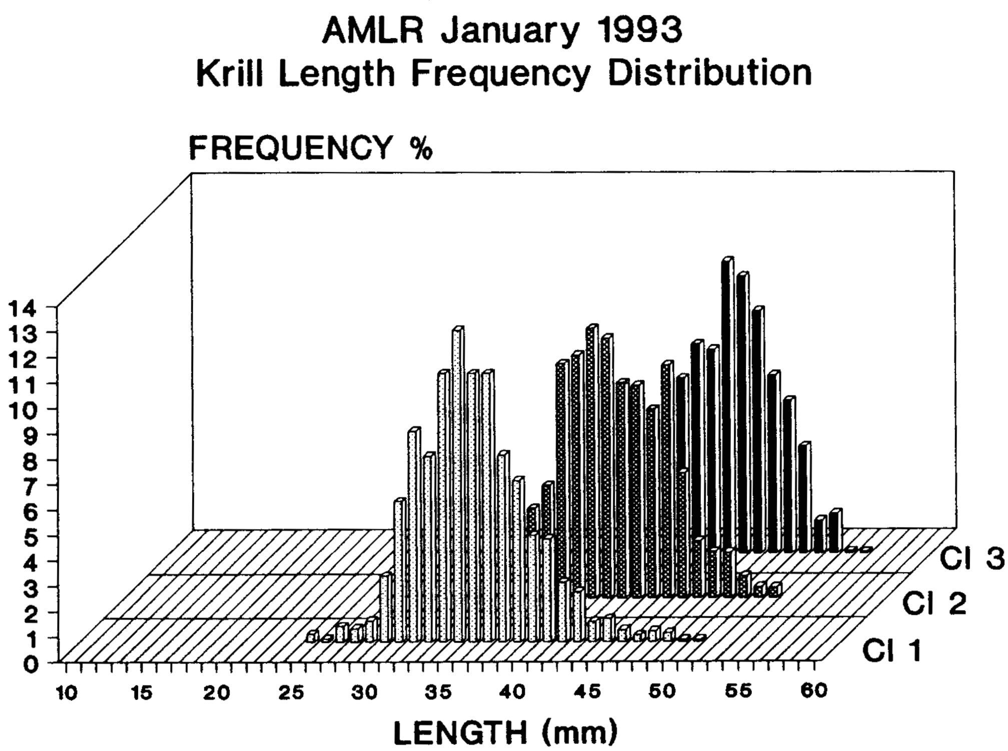


Figure 4.2b Length frequency distributions of krill belonging to three different length categories present in the Survey A area as determined by cluster analysis.

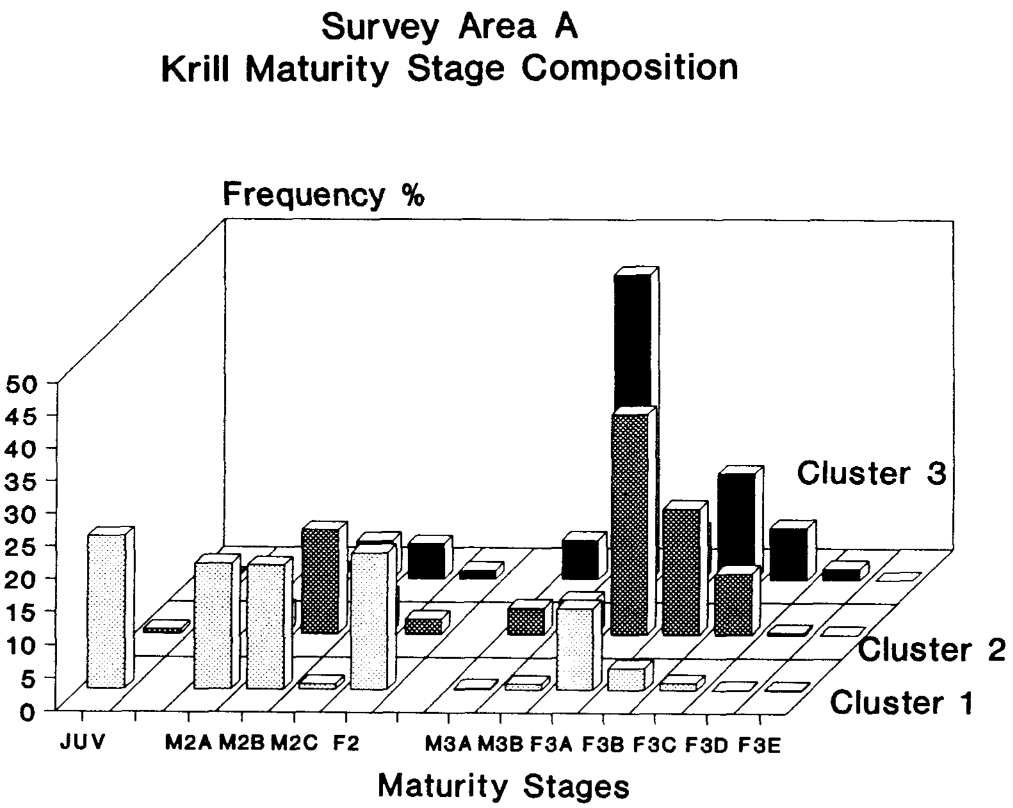


Figure 4.3 Maturity stage composition of krill associated with the three different length categories (clusters 1-3) present in the Survey A area.

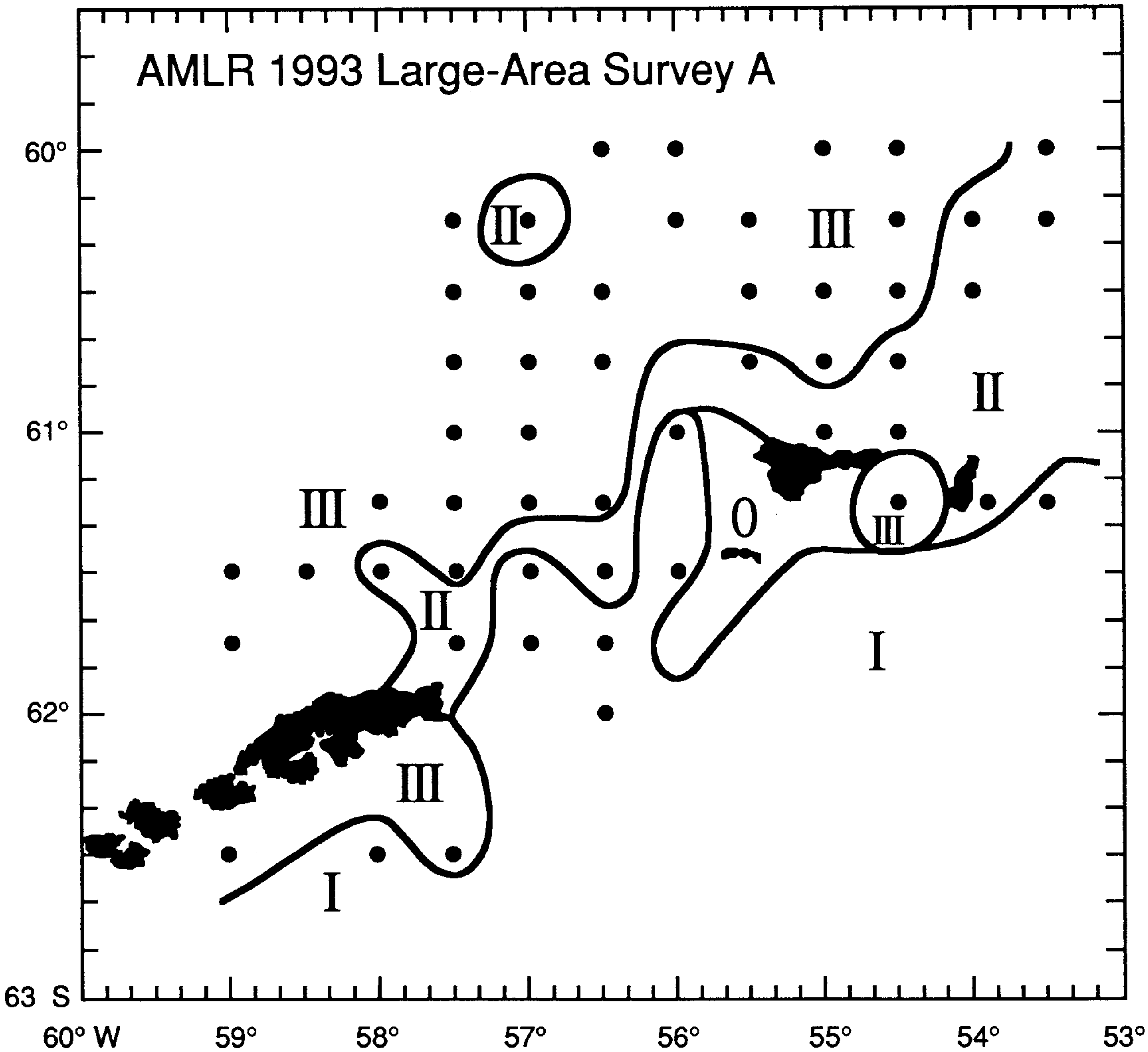


Figure 4.4 Distribution of krill belonging to three different length frequency categories (clusters 1-3) in the Survey A area, January 1993.

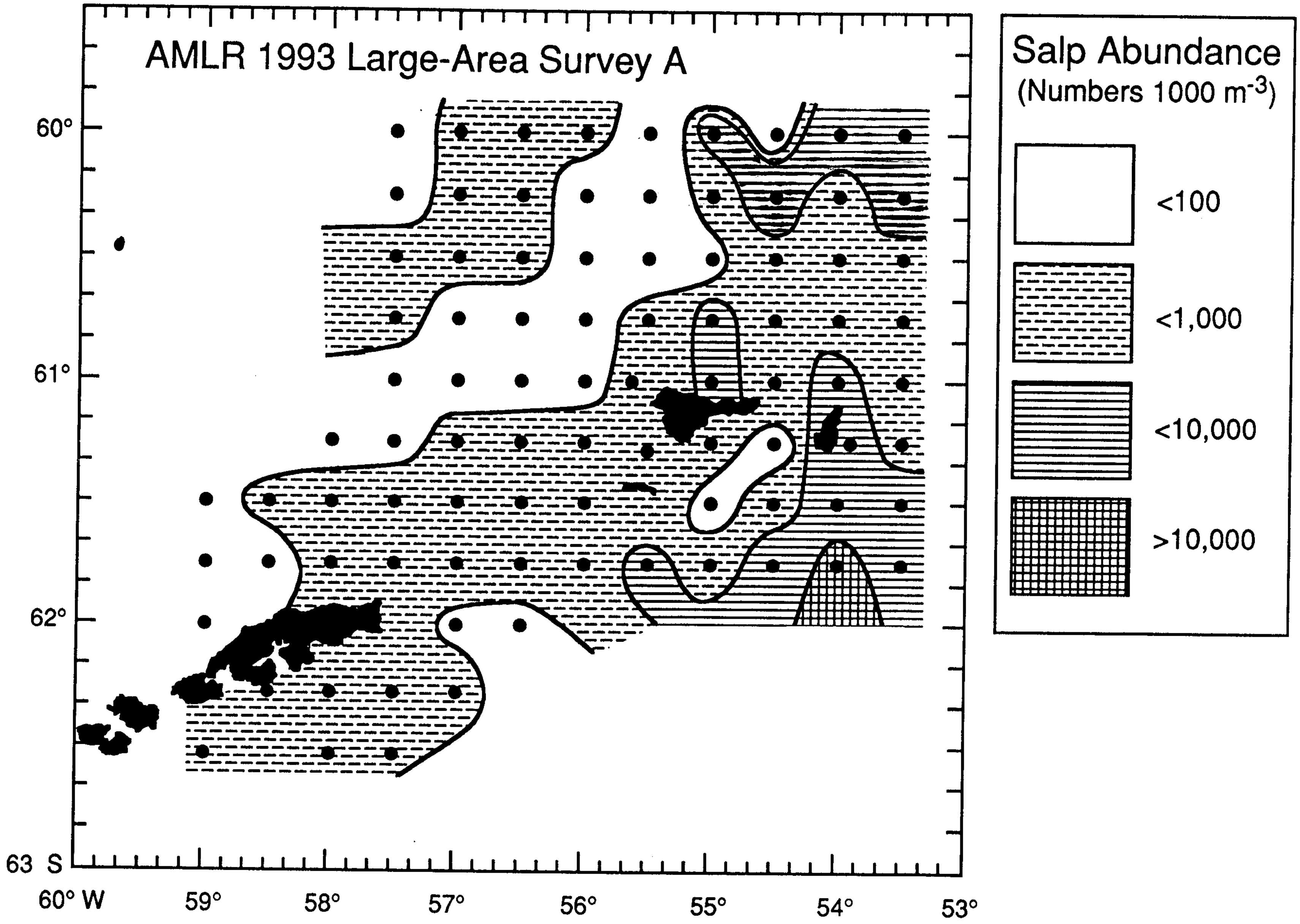


Figure 4.5 Distribution and abundance of *Salpa thompsoni* in the Survey A area.

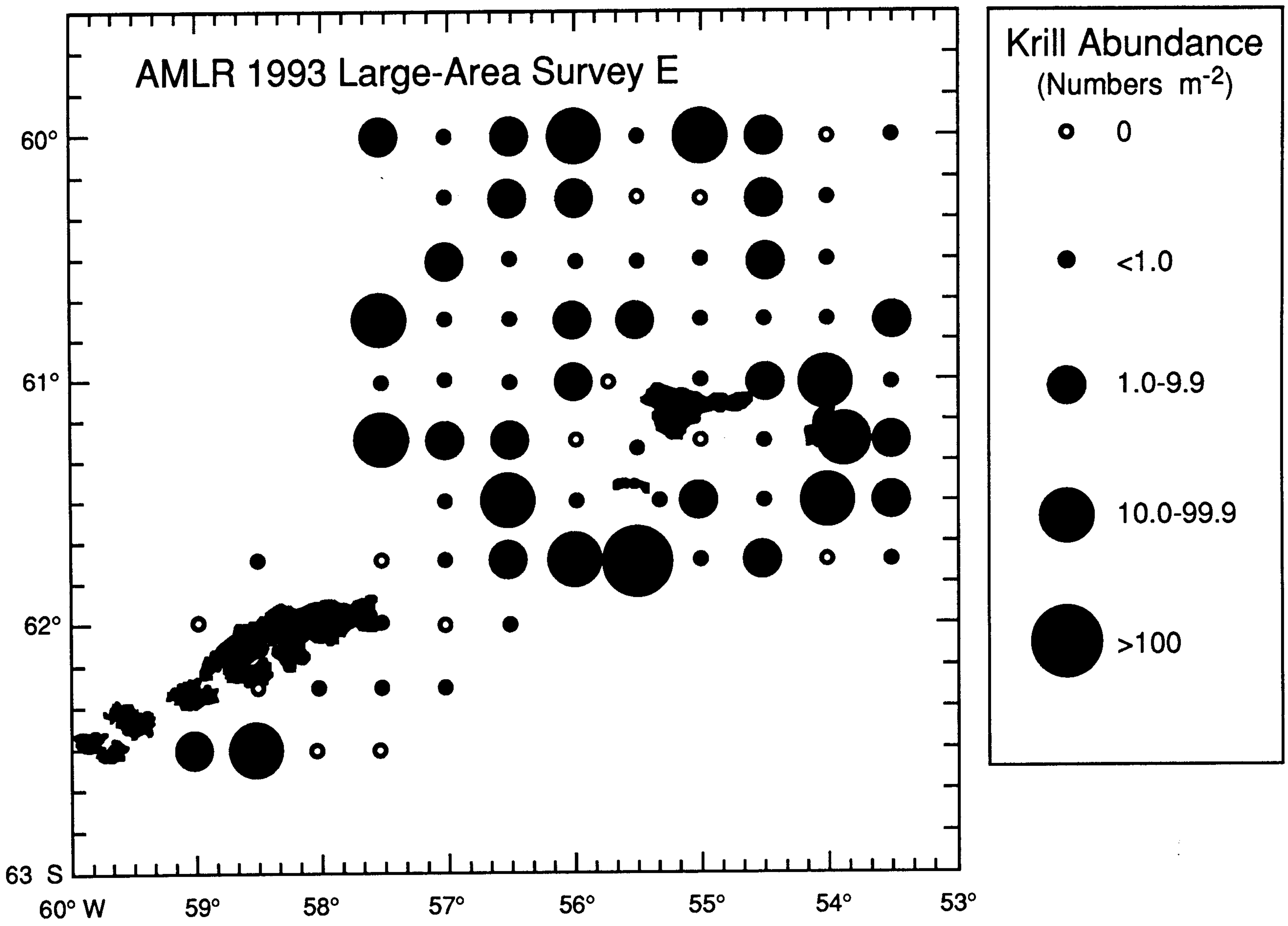


Figure 4.6 Krill abundance in IKMT tows collected during Survey E, February-March 1993.

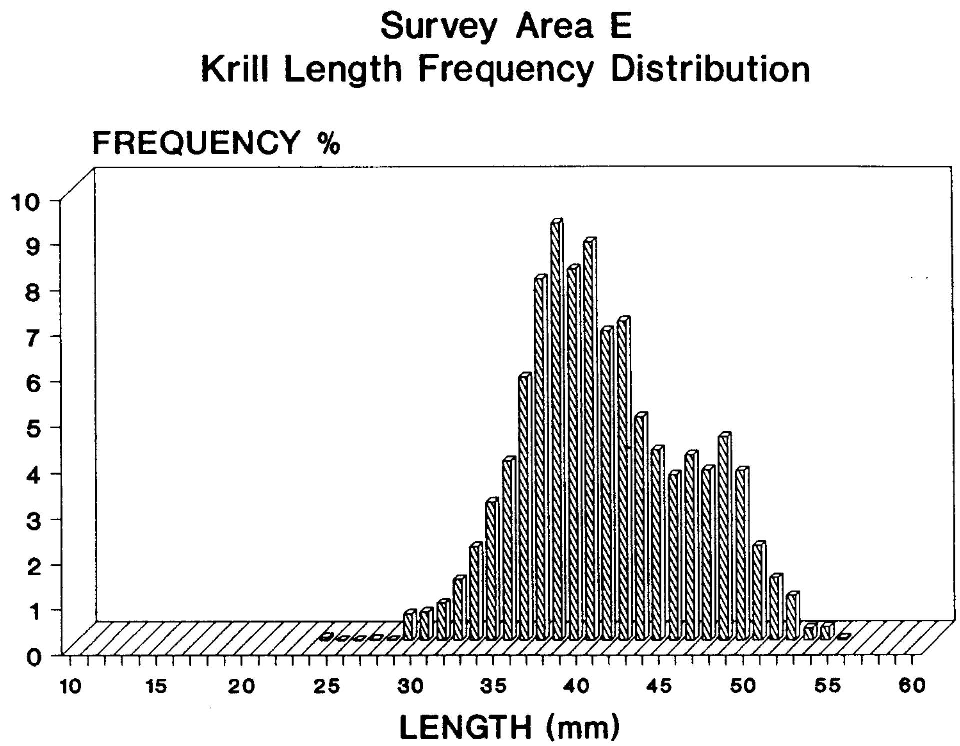


Figure 4.7a Overall length frequency distribution of krill collected during Survey E.

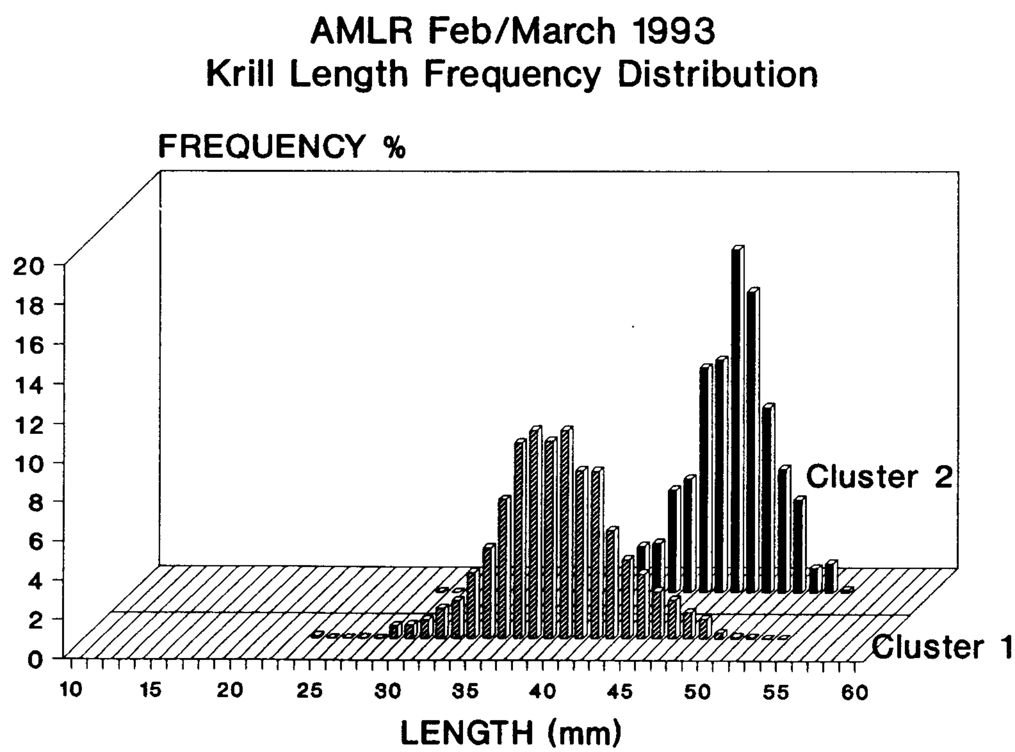


Figure 4.7b Length frequency distributions of krill belonging to two different length categories present in the Survey E area as determined by cluster analysis.

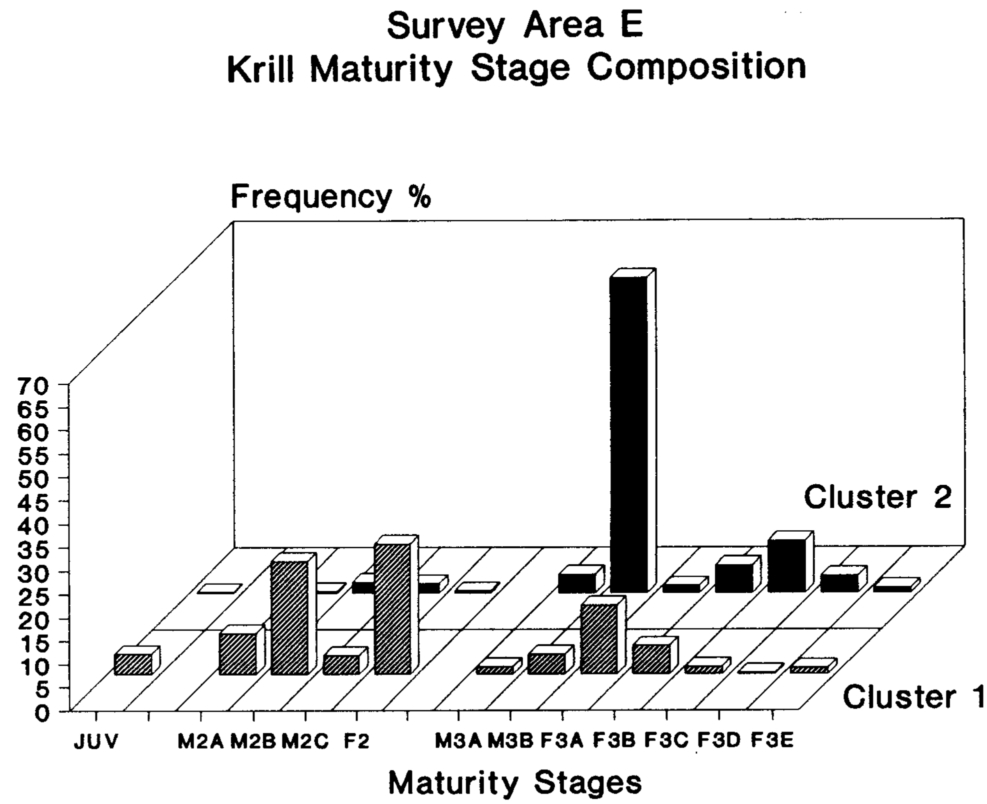


Figure 4.8 Maturity stage composition of krill associated with the two different length categories (clusters 1 and 2) present in the Survey E area.

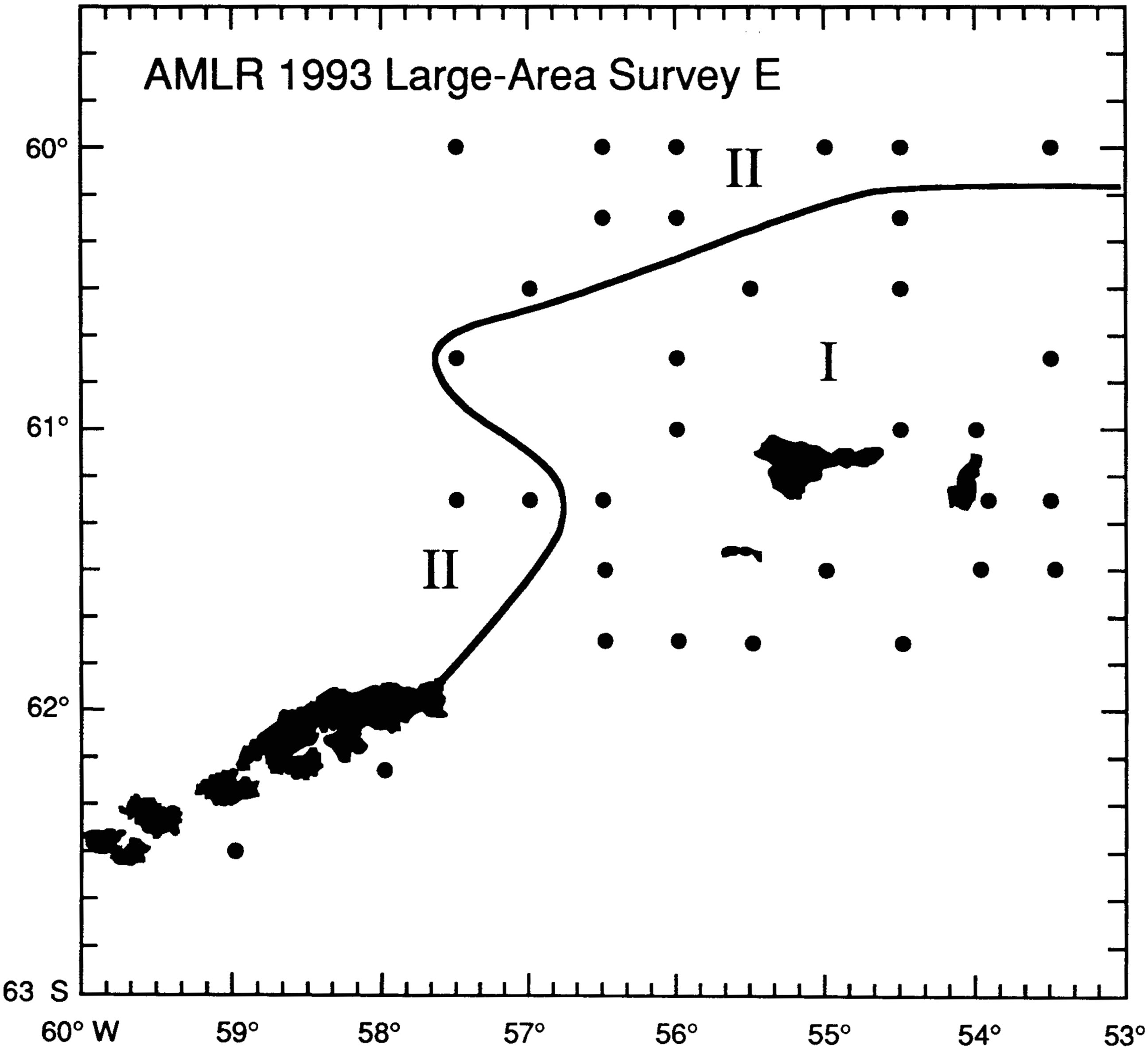


Figure 4.9 Distribution of krill belonging to two different length frequency categories (clusters 1-2) in the Survey E area, February-March 1993.

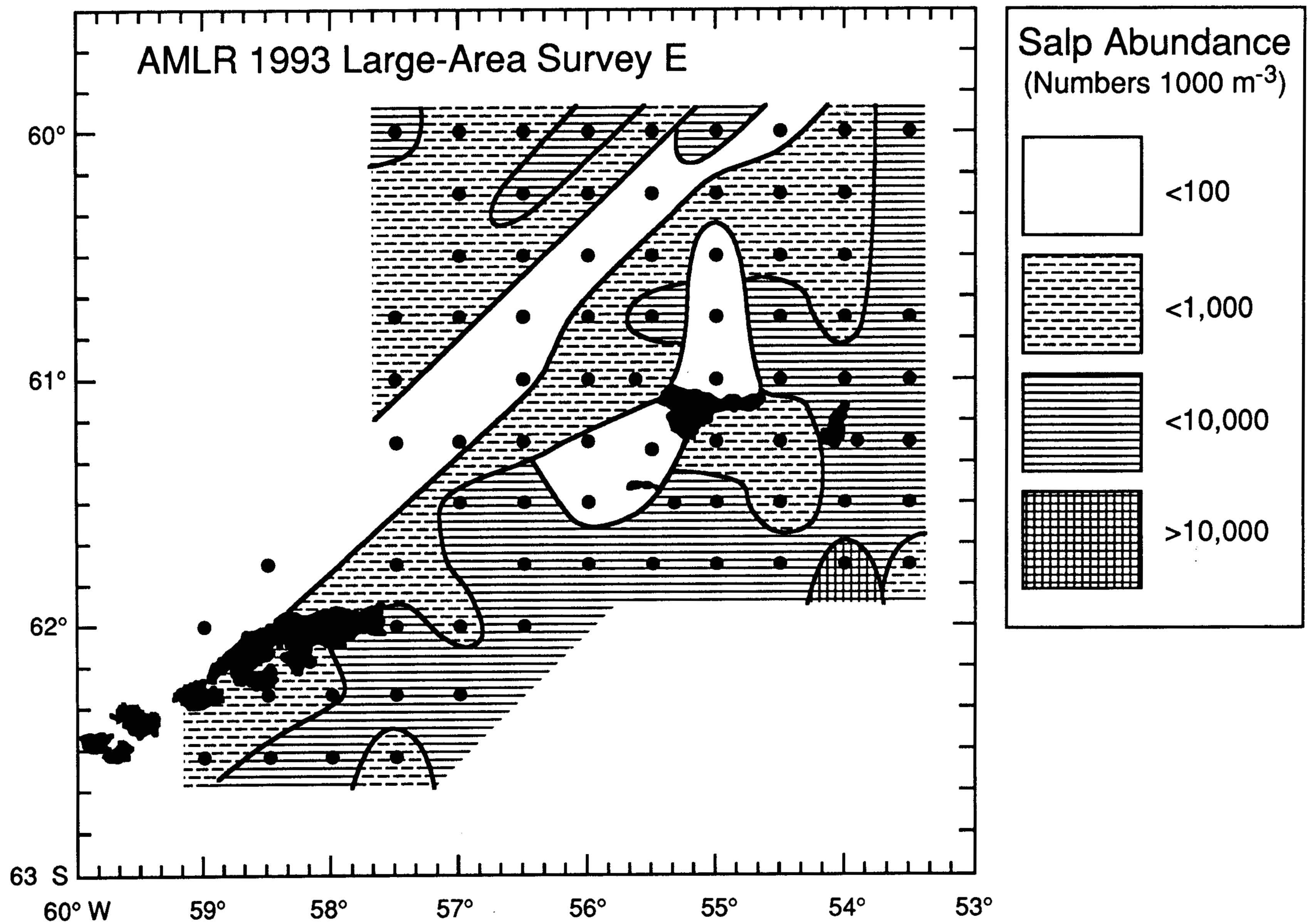


Fig 4.10 Distribution and abundance of *Salpa thompsoni* in the Survey E area.

5. Seabird and cetacean ecology; submitted by Richard Veit (Leg I), Gabrielle Nevitt (Leg II), Beverly Agler (Legs I and II), Martha Groom (Leg II), Daniel Grunbaum (Leg I), David Secord (Leg II), and Emily Silverman (Leg I).

5.1 Objectives: Our intent in joining the 1993 AMLR cruise was to determine whether spatial variations in krill abundance influence the distributions of marine birds and mammals. We geared our efforts towards understanding whether aggregations of birds or mammals coincide spatially with aggregations of krill. In addition, we tried to identify specific behavioral events that might contribute to the formation of large aggregations of bird predators in the vicinity of krill swarms.

5.2 Methods: To accomplish these objectives, one observer counted birds and mammals along transect lines at the same time that krill abundance was being monitored acoustically. Observations were restricted to a 100m x 100m "box", 50m off the ship's bow, which roughly coincided with the area of the acoustic survey. We found that a single observer was able to effectively collect and record data using a hand-held computer. At the same time, two other observers recorded behavioral observations of individual birds in the area, but not necessarily restricted to the box. Behavioral observations included movement activity (flying, porpoising, diving, milling, sitting on water), the direction of travel, and any additional behaviors observed (i.e., feeding, looking in the water, preening). For behavior data collection, observers took turns calling out observations and entering data into hand-held computers. Once a bird was sighted, observations continued until the observer could no longer see the bird (typically 1-2 minutes). For all areas surveyed (Leg I, Surveys A, B and C and Leg II, Surveys D, E and F), data collection was limited to daylight hours. Therefore, our ability to analyze the spatial relationships between krill, birds, and mammals was restricted to about two-thirds of the total survey area.

5.3 Results and Conclusions:

1. Associations between Seabirds and Krill:

During this season, seabirds were widely dispersed over the survey grids (Figures 5.1 and 5.2), and we saw no large (thousands of individuals) aggregations of feeding birds. This distribution was very different from that in 1989, when both krill and birds were much more highly aggregated. However, the distribution of birds this season was patchy, and we did see feeding flocks containing up to a few hundred birds, especially on Leg II. We also made numerous observations of birds feeding. For example, chinstrap penguins were often observed sitting on the water, preening, looking in the water, and diving, all behaviors which reflect feeding activity. During both legs we observed several groups of up to 1000 individual antarctic fulmars resting on the water. Most of these groups were observed seaward of the shelf-break, north of Elephant Island. We hypothesize that these birds had probably been feeding during the previous night near the area where we observed them the next morning. Fulmars, like many of the seabirds in this region, feed in the upper meter of the water column where krill typically concentrate at night. During Leg I, we made numerous observations of cape petrels capturing prey. Cape petrels are another species that feeds heavily on krill. On several hundred occasions we saw individual cape petrels plunge one meter or more beneath the surface, and we assume that they were pursuing prey. Based on our previous experience, it is uncommon to see cape petrels plunging in this fashion outside of a major feeding aggregation. The suggestion is that these birds were pursuing widely dispersed, small patches of krill. Of interest was the lack of spatial concordance between aggregations of birds and aggregations of cetaceans (Figures 5.2 and 5.3). This lack of concordance suggests that cetaceans prey on different (possibly deeper and denser) patches of krill than do birds.

On Survey A (the only data we have so far analyzed), we found a statistically significant association between abundance of chinstrap penguins and estimated krill abundance. The strength of this association varied with the bin size over which we integrated bird and krill abundance. Using segments ranging in length from 0.1 n.mi. to 1.6 n.mi., we obtained spatial correlation coefficients of 0.1 to 0.31. These values are similar to ones we have obtained for spatial association between macaroni penguins and krill near South Georgia. Figure 5.4a shows a transect off the east end of Elephant Island on which we encountered large numbers of penguins. Whereas one "peak" of penguins coincided with one "peak" of krill, the alignment between predators and prey was far from exact. Figure 5.4b shows the spatial correlation between krill and penguins for the same transect, calculated at a scale of 0.5 n.mi. Through analysis of bird behavior, we hope to learn how such patterns of bird distribution might arise as a consequence of the "rules" they use in searching for prey. We found no statistical association between krill abundance and numbers of Antarctic Fulmars or numbers of Cape petrels. We suspect the main reason for this apparent lack of association is that we are unable to acoustically sample the upper few meters of the water column, that region accessible to non-diving birds.

Possibly, a more detailed analysis of the accessibility of krill to birds will reveal more compelling evidence for the association between predators and krill. For example, the largest aggregation of antarctic fulmars observed during Leg I was situated directly over a patch of salps and krill detected close to the surface. Since this patch was not especially dense, it is not evident in the distributional map of krill biomass; yet it may be that the patch was particularly easy for the foraging birds to reach. Our results may also reflect a time delay between observed feeding events and measurements of krill abundance. We aim to incorporate this error into our analysis by testing whether distances between krill and bird aggregations differ from random expectation.

We speculate that the differences in abundance of penguins observed during Leg I vs. Leg II may be attributed to an increase in the overall food-load demand by chicks during the later part of the breeding season. Such increased food needs could potentially require foraging efforts by both parents, and may in part reflect the apparent increases in penguin abundances observed. In addition, foraging activity by fledglings could contribute to increased numbers of chinstraps observed during Leg II.

2. Southward Shifts in Distribution:

On both surveys, we recorded elevated densities of species that are ordinarily distributed farther north than the Elephant Island area. These species (white-chinned petrels and light-mantled sooty and gray-headed albatrosses), in addition to having more northerly distributions, feed mainly on squid and fish rather than krill and tend to forage over highly pelagic waters. Figure 5.5 shows that white-chinned petrels were largely restricted to the Drake Passage and Transitional waters identified by Amos et al.; the distribution of the two albatrosses just mentioned was similar. Our data suggest that conditions in these offshore zones were especially good for foraging for these offshore species during 1993. Perhaps related to the increased abundance of northerly, pelagic species near Elephant Island, was the elevated abundance of two other northerly (but not pelagic) species, rockhopper penguins and manx shearwaters. Rockhopper penguins, which are only rarely found south of the Polar Front, were present in flocks of up to 25 birds within 75 miles of Elephant Island during Leg I. Several hundred manx shearwaters were seen on a transect between Staten Island and the Strait of Magellan on February 8th; this species is ordinarily uncommon south of central Argentina.

During the large-area surveys, we noticed a distinct separation in bird species composition across the shelf-break north of King George and Elephant Islands. Dove prions, white-chinned petrels, and grey-headed and light-mantled sooty albatrosses were common north of the shelf-break but scarce south of it. During Leg I, flocks of antarctic fulmars were consistently found seaward of the shelf-break, suggesting that their prey may have been concentrated by physical mechanisms associated with the shelf-break front.

3. Cetaceans:

Marine mammals were present in higher numbers than previously recorded. We sighted twice as many humpback whales (29 individuals in 11 sightings) as in either 1992 (14 individuals) or 1990 (6 individuals). Humpback whales are our target species for obtaining individual identifications using photographs of the underside of tail flukes. We attempted to obtain photographs from approximately 7 sightings; we probably photographed 5 individuals well enough for inclusion in the Antarctic Humpback Whale Catalog maintained by College of the Atlantic, Bar Harbor, Maine. Other sightings of large cetaceans included: fin whales (37-42 individuals) and minke whales (22 individuals). Sei whales (4 individuals) were sighted for the first time on these surveys. During Leg I, a minke whale followed the ship closely for over 2 hours. The whale surfaced repeatedly very near the towed acoustic array. During Leg II, we observed 3 humpback whales rolling and flipper slapping within 20m of the ship during a CTD cast. Marine mammal sightings are summarized in Table 5.1.

Sightings of toothed whales included: southern bottlenose whales (12 individuals), long-finned pilot whales (105 individuals), and hourglass dolphins (182-190 individuals).

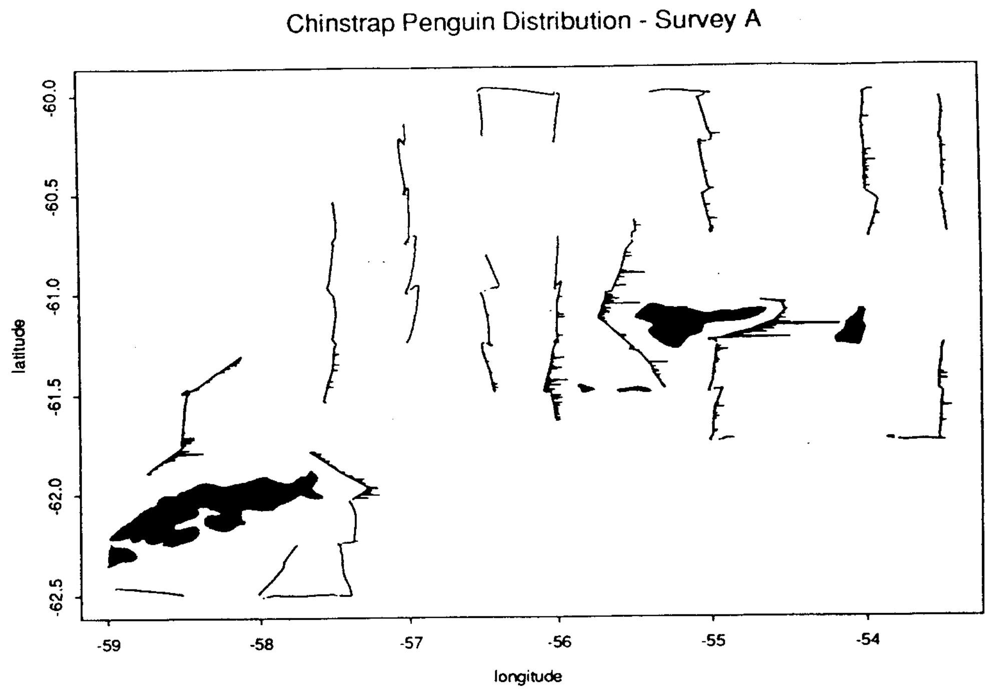
We also had several sightings of mesoplodon sp. (7 individuals) and other beaked whales (2 individuals). It is highly probable that one of the mesoplodon sp. sightings was actually Arnoux's beaked whale. A pod of approximately 30 orcas was observed within one-half mile of a sighting of 5 humpback whales.

4. Bird Species List: Legs I and II:

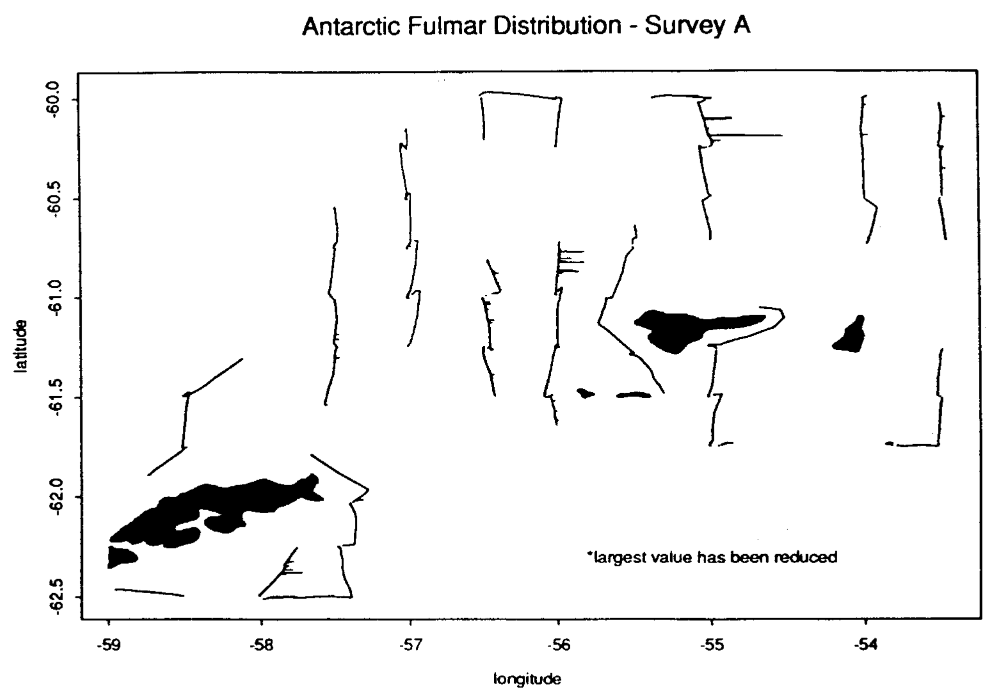
Gentoo penguin - small numbers off west end of Elephant Island.
Chinstrap penguin - abundant.
Adelie penguin - ten individuals seen.
Macaroni penguin - uncommon; in groups of chinstraps.
Rockhopper penguin - about 100 seen in Drake Passage (Leg I).
Wandering albatross - uncommon; one breeder from South Georgia was identified by color mark (Leg I).
Royal albatross - one photographed off Elephant Island. Several north of Elephant Island on Leg II.
Black-browed albatross - common.
Grey-headed albatross - about 75 seen; most north of shelf-break.
Light-mantled sooty albatross - more numerous than average.
Northern giant-petrel - about 50 seen; mostly north of the shelf-break.
Southern giant-petrel - common.
Antarctic petrel - one seen north of Elephant Island (Leg I).
Cape petrel - common.
Snow petrel - 5 seen (Leg I); 3 seen (Leg II).
Antarctic fulmar - common.
Blue petrel - common in Drake Passage during first half of Leg I; scarce thereafter.
Antarctic prion - common in Drake Passage. One feeding flock of 500 seen (Leg I).
Thin-billed prion - about 20 identified.
Soft-plumaged petrel - 3 seen during large-area survey (Leg I); common in the northern part of the survey grids (Leg II).
White-chinned petrel - 100's seen; much more numerous than usual.
Sooty shearwater - common in northern Drake Passage (Leg I and II); 5 seen during large-area survey (Survey E; Leg II).
Manx shearwater - 100's seen north of Staten Island.
Wilson's storm-petrel - common.
Black-bellied storm-petrel - common.
Diving-petrel, sp. - 2 seen (Leg I); 2 seen (Leg II). Common in northern Drake Passage.
Blue-eyed shag - about 50 seen in vicinity of Seal Island (Legs I and II).
South polar skua - uncommon.
Brown skua - uncommon; a few ship followers (Leg II)
Pomarine jaeger - one worn adult seen in northern Drake Passage (Leg I).
Southern black-backed gull - about 10 seen.
Antarctic tern - uncommon.
South American tern - common off Argentina.
Yellow-billed sheathbill - about 15 seen (Leg I).
Little shearwater - 1 seen (Leg II)

Table 5.1 Marine mammal sightings during AMLR 93.

	Drake Passage				Large-Area		Small-Area					
SPECIES	**Drake 1**	**Drake 2**	**Drake 3**	**Drake 4**	**Survey A**	**Survey E**	**Survey B**	**Survey C**	**Survey D**	**Survey F**	**Bransfield**	**Total**
Seals												
Antarctic Fur Seal			2 (2)		44 (30)	33 (27)	29 (21)	19 (16)	12 (8)	17 (10)	4 (3)	160 (117)
Weddell Seal					1 (1)							1 (1)
Possible Leopard Seal							1 (1)					1 (1)
Dolphins												
Commerson's Dolphin	3 (3)		1 (1)									4 (4)
Hourglass Dolphin	11 (2)	21-29 (4)	22 (6)	2 (1)		30 (6)	10 (1)		14 (5)	18 (3)		182-190 (28)
Orca					1 (1)	30 (1)						31 (2)
Pilot Whale					30 (1)		75 (1)					105 (2)
Lagenrhynchus spp.				24 (2)								24 (2)
Whales												
Minke Whale		2 (2)	2 (2)		8 (7)	7 (3)			1 (1)	2 (2)		22 (17)
Sei Whale						3 (1)				1 (1)		4 (2)
Fin Whale			25-30 (1)			9 (2)			3 (1)			37-42 (4)
Prob. Fin/Sei Whale		2 (1)			2 (2)							4 (3)
Unid. Balaenoptera				1 (1)	1 (1)							2 (2)
Humpback Whale					12 (5)	14 (4)			1 (1)		2 (1)	29 (11)
Southern Bottlenosed Whale				1 (1)	3 (2)	4 (1)			1 (1)	3 (1)		12 (6)
Poss. Minke / Bottlenosed Whale	2 (1)											2 (1)
Mesoplodon sp.				2 (1)		1 (1)				4 (1)		7 (3)
Beaked Whale sp.		2 (1)										2 (1)
Unid. Whales			3 (2)			2 (2)			4 (1)	4 (3)		13 (8)
Dead Whales - prob. Minke Whale						1 (1)	1 (1)					1 (1)



(a)



(b)

Figure 5.1 AMLR 1993 Survey A. Spatial distribution of (a) chinstrap penguins and (b) antarctic fulmars, species that feed substantially upon antarctic krill. Vertical lines represent the sections of the survey sampled for birds, and horizontal lines represent the abundance of birds in each 0.1 n.mi. segment. Gaps in the pattern were samples at night. N = 7841, 0.1 n.mi. segments.

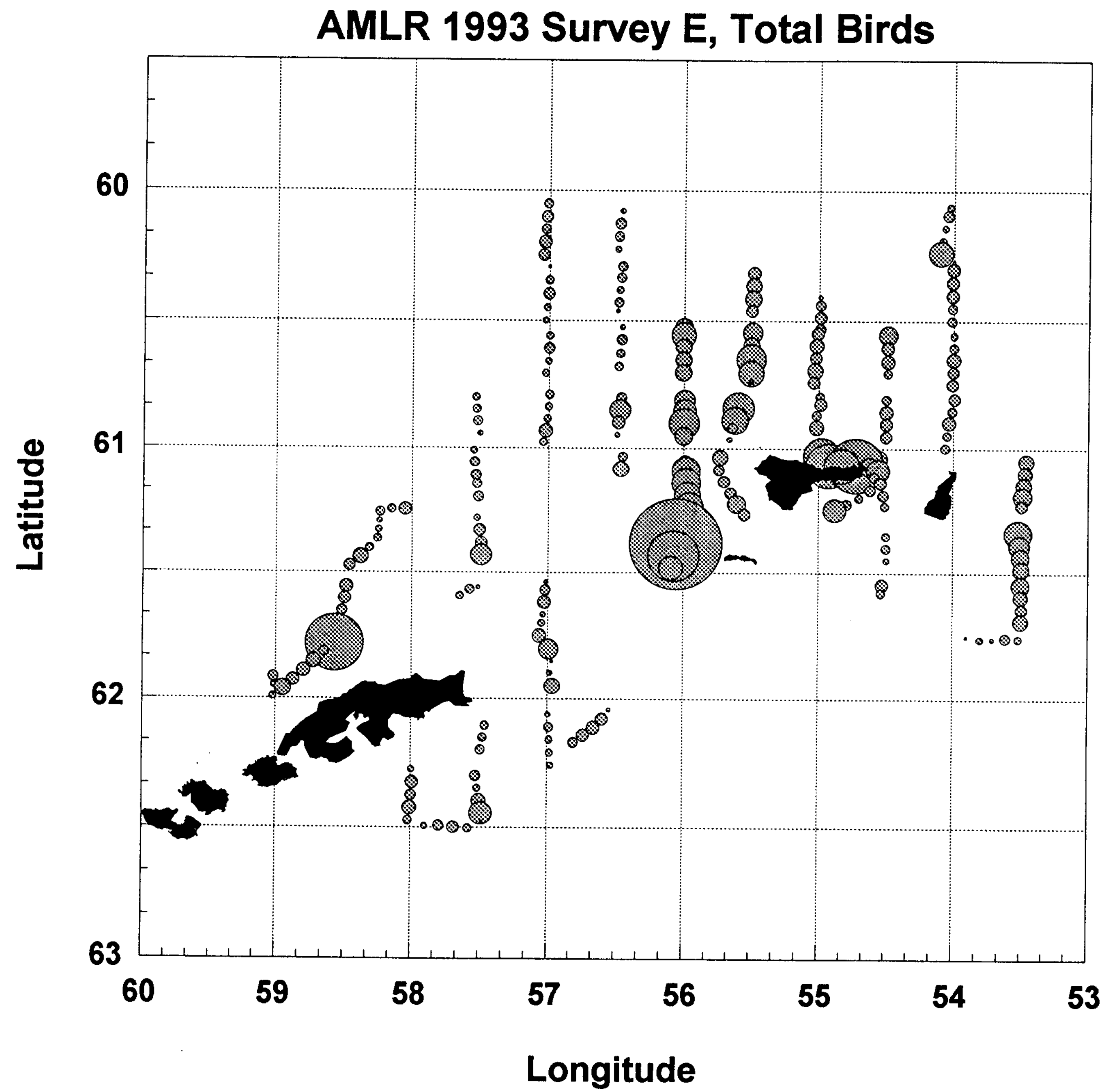


Figure 5.2 AMLR 1993 Survey E. Spatial distribution of total birds. Diameter of grey circles is proportional to bird abundances.

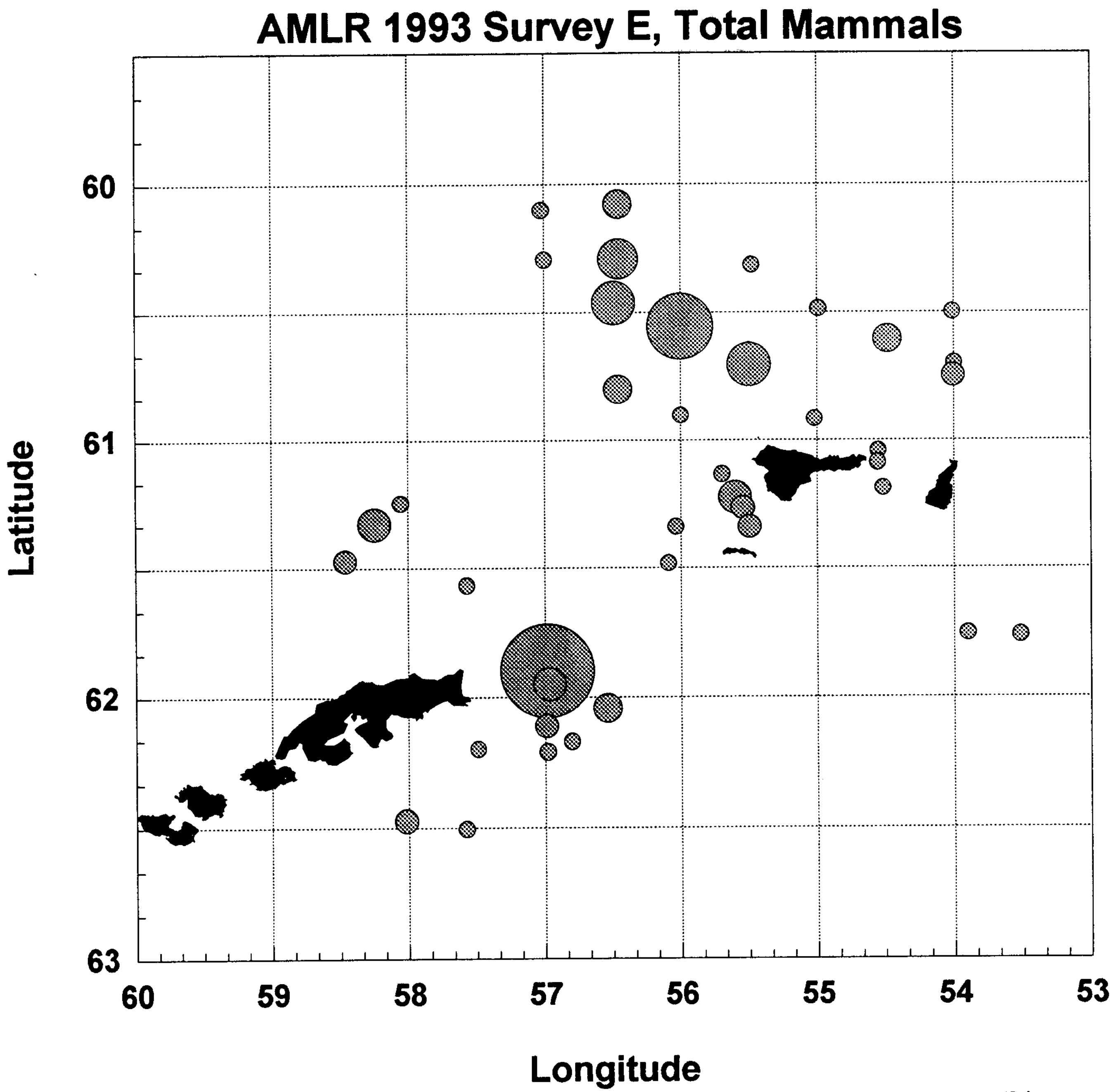
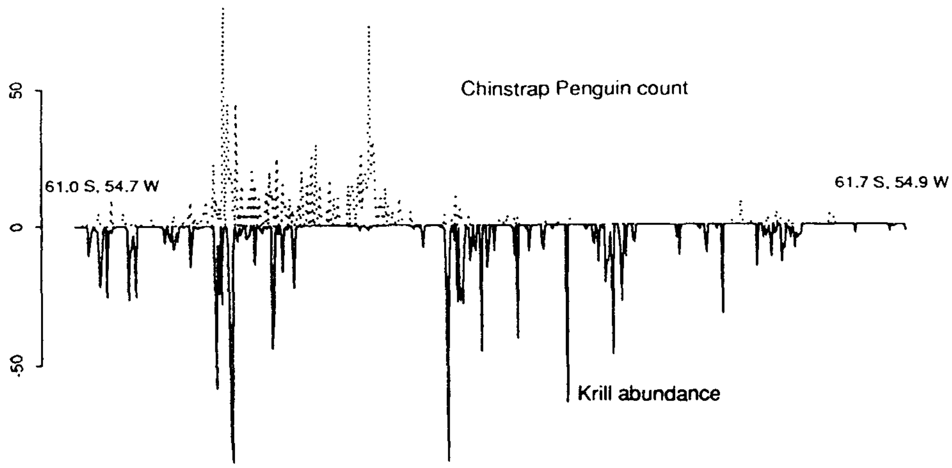


Figure 5.3 AMLR 1993 Survey E. Spatial distribution of total mammals. Diameter of grey circles is proportional to marine mammal abundances.



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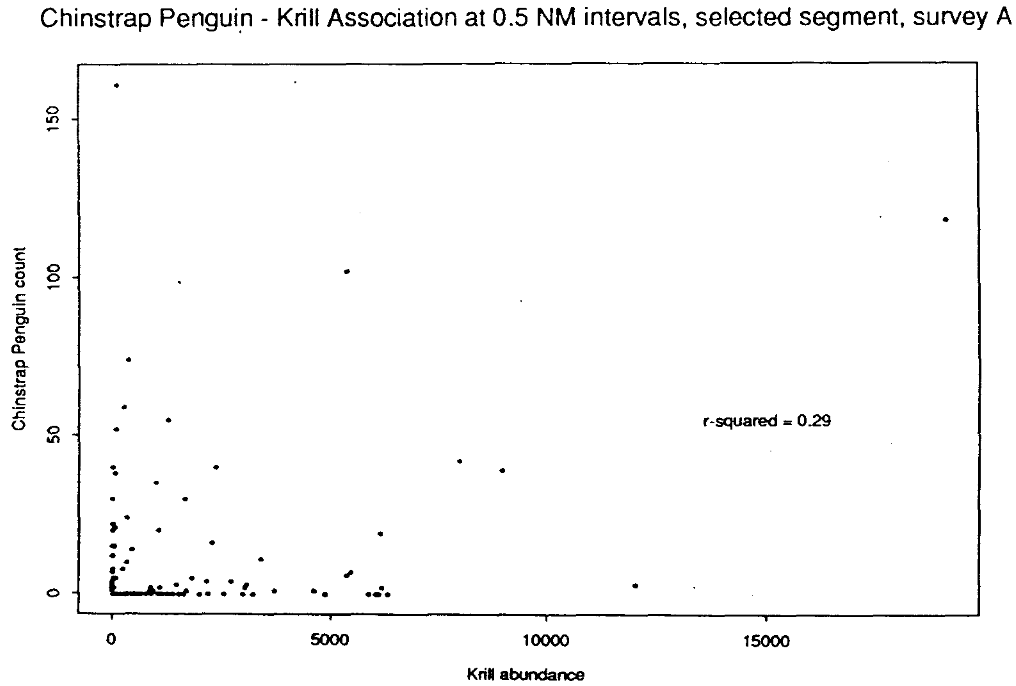


(b)

Figure 5.4 AMLR 1993 Survey A. (a) Spatial association between chinstrap penguins and antarctic krill between Stations 64 and 66, east of Elephant Island, 27 January 1993. Both the penguin counts and indices of krill abundance have been standardized to the same scale; penguin counts are represented on the positive y-axis, and krill abundance on the negative y-axis. (b) Spatial correlation between chinstrap penguins and krill on the 27 January transect. N = 115 0.5 n.mi. segments.

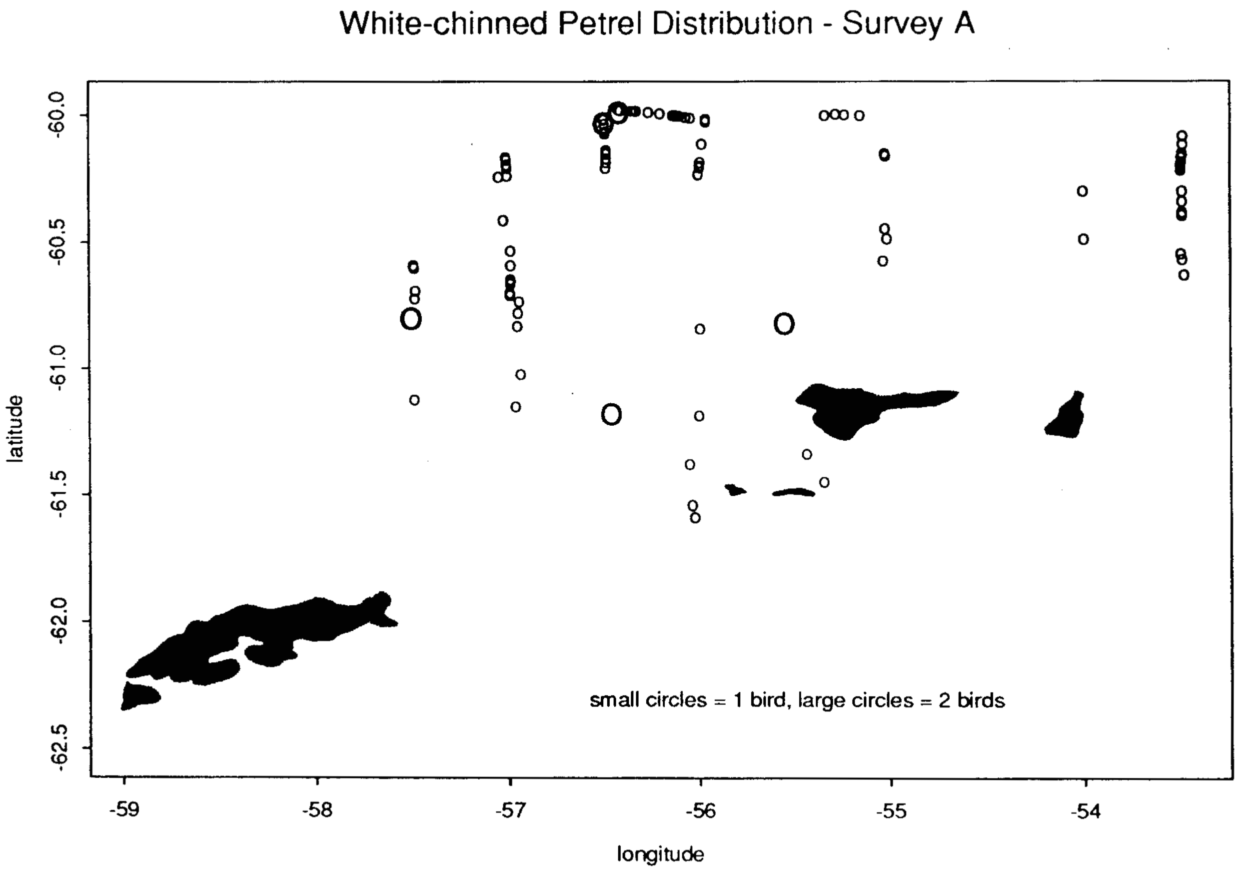


Figure 5.5 AMLR 1993 Survey A. Spatial distribution of white-chinned petrels. Sections that were surveyed in which no birds were observed have not been plotted.

6. CCAMLR Inspection of Polish krill fishing vessel, Lyra; submitted by Alexandra R. Von Saunder.

On 3 March 1993, two U.S. CCAMLR inspectors from the NOAA Ship *Surveyor* boarded the Polish fishing vessel, *Lyra*, in order to verify compliance with measures adopted under the CCAMLR. The boarding of the krill fishing vessel occurred at the position of 60°51'S and 55°40'W, about 12 miles north of Elephant Island in the South Shetland archipelago.

The two inspectors, Chief Scientist Roger Hewitt and Ensign Alexandra Von Saunder, boarded the *Lyra* at approximately 1925GMT. They were greeted by the vessel's Captain, K. Wisniewski. After presenting Captain Wisniewski with their authorized inspector identification cards and briefly discussing the scarcity of krill this season, Dr. Hewitt and ENS Von Saunder began the inquiries necessary to complete the CCAMLR Report of Inspection form. The questions posed followed the basic format of the report form, including questions regarding the vessel, the fishing gear used, the vessel's catch, and events recorded in the ship's logbooks.

All of the Captain's responses seemed reasonable and matched with the various documents, net plans, and logbooks that he willingly presented to aid the inspection. The essential facts of the inspection were noted on the CCAMLR report form. Following completion of the inquiries, Captain Wisniewski gave a tour of the vessel, including the bridge and echosounding equipment used to find large quantities of krill, the fishing-deck bridge where the nets are controlled and towing events logged, and the factory where the krill meat is separated from the shells and frozen. The factory was set up for krill processing only, and it did not appear that other types of fish meat could have been processed.

No infringements to the Commission's measures were found as a result of the inspection; the procedures in use on the *Lyra* appeared to be in accordance with CCAMLR's regulations. Before disembarking the vessel, the Captain signed the completed CCAMLR report and was given a copy for his records. Captain Wisniewski was very cooperative and receptive to the inspectors' questions concerning official CCAMLR business and also less formal topics about the vessel's fishing history.

7. Polycyclic aromatic hydrocarbons around the South Shetland Islands, Antarctica. Thermal structure of Drake Passage 1993; submitted by Christian Bonert Anwandter (Leg II).

7.1 Objectives: During Leg II of AMLR 93, two research projects were conducted by Servicio Hidrográfico y Oceanográfico de la Armada de Chile (SHOA). The objective of the first project was to establish the background concentrations of Polycyclic Aromatic Hydrocarbons (PAH) and the identification of specific PAH components in surface antarctic waters around the South Shetland Islands.

The objective of the second project was to continue the XBT observations started during the AMLR 1990 cruise for monitoring the thermal structure of the upper layers of the Drake Passage.

7.2 Accomplishments: Twelve water samples were collected around Elephant, King George, and Deception Islands. The content and identification of specific components of dissolved and dispersed hydrocarbons will be analyzed by spectrofluorometry, HPLC, and Gas Chromatography at the laboratory of SHOA, Valparaiso, Chile.

Twelve XBT observations were conducted while crossing the Drake Passage at the beginning of Leg II (February 15-16) from about 35 n.mi. south of Isla de los Estados to about 18 n.mi. offshore of Elephant Island. During the return crossing (March 12-13), another 12 XBT casts were done at approximately the same positions as the previously described track.

From the XBT data, it is possible to locate the Polar Front in the first crossing between 58°22'S, 59°35'W and 58°02'S, 60°07'W, and in the second crossing between 57°44'S, 59°56'W and 57°32'S, 60°22'W.

The author wishes to thank the AMLR Program and the officers and crew of the NOAA Ship *Surveyor* for making these studies possible. My gratitude is extended to Dr. Osmund Holm-Hansen for his collaboration in the development of my tasks.

8. Activities during the southbound transit; submitted by Larry Spear, Dan Christian, and Anthony Amos.

(1) Bird and mammal observations from Seattle to Valparaiso, Chile; submitted by Larry Spear and Dan Christian.

Our main objective on the Southbound transit of the *Surveyor* from Seattle to Valparaiso was to increase our database for a study of distribution and density of seabirds and marine mammals off the coast of Peru. In addition, we used the opportunity to census other areas along the transit trackline where permission had been arranged. We were interested in seabird distribution as related to environmental features including sea-surface temperature and salinity, thermocline depth and profile, ocean depth, distance from land, and wind speed and direction.

We censused seabirds continuously during daylight hours when the ship was underway. Observations were made by two observers simultaneously, counting seabirds that came within a 90° quadrant and within 400m of one forequarter of the ship. We recorded mammals that came within 1000m of the same forequarter. We divided censuses into half-hour transects, except off Peru where we used 15 minute transects. Data on environmental variables were recorded on the bridge or were provided by the ship's survey department.

For this report, we divided the transit into seven regions: North America (NA), Nicaragua (NI), Costa Rica (CR), Ecuador (EC), northern Peru (NP), southern Peru (SP), and northern Chile (NC). Hours of transect time and surface area surveyed (km^2) for the seven regions included: NA (31.1hr, 319.3km^2); NI (34.3hr, 322.9km^2); CR (12.5hr, 133.1km^2); EC (12.3hr, 119.0km^2); NP (25.3hr, 259.0km^2); SP (26.3hr, 269.7km^2); NC (40.4hr, 365.7km^2). Distance from shore in nautical miles (n.mi.) for surveys off the seven regions were: NA (40-114 n.mi.), NI (42-80 n.mi.), CR (Cocos Island; 35-197 n.mi.), EC (67-147 n.mi.), NP (5-52 n.mi.), SP (3-56 n.mi.), and NC (5-200 n.mi.).

A summary of results for the censuses of birds are reported in Table 8.1, and a summary for marine mammals in Table 8.2.

(2) Other observations during southbound transit.

Underway environmental observations were made during the transit by a system provided by Anthony Amos. Data collected included: ship's position, wind speed and direction, air temperature, humidity, barometric pressure, light levels at several spectra, sea surface temperature and salinity (see Section 1 for details), as well as light beam transmission and fluorescence in permitted areas (see Sections 1 and 2 for details).

The system was operated during the transit for two reasons: (1) to reveal any problems with the system prior to the start of work in the antarctic, and (2) to provide other scientists working aboard *Surveyor* underway navigation and environmental data.

Table 8.1 Species of birds seen by region and relative number. A = abundant, C = common, R = regularly seen but not common, F = few seen, dashed line = none seen. Abbreviations for regions are NA = North America, NI = Nicaragua, CR = Costa Rica, EC = Ecuador, NP = northern Peru, SP = southern Peru, NC = northern Chile.

	NA	NI	CR	EC	NP	SP	NC
Humboldt Penguin *Spheniscus humboldti*	--	--	--	--	--	F	F
Pacific Loon *Gavia pacifica*	F	--	--	--	--	--	--
Black-browed Albatross *Diomedea melanophris*	--	--	--	--	--	F	--
Salvin's Albatross *Diomedea cauta salvini*	--	--	--	--	F	C	--
Laysan Albatross *Diomedea immutabilis*	R	--	--	--	--	--	--
Black-footed Albatross *Diomedea nigripes*	R	--	--	--	--	--	--
Waved Albatross *Diomedea irrorata*	--	--	--	--	A	C	--
White-chinned Petrel *Procellaria aequinoctialis*	--	--	--	--	C	C	C
Parkinson's Petrel *Procellaria parkinsoni*	--	--	--	F	R	F	F
Northern Fulmar *Fulmarus glacialis*	A	--	--	--	--	--	--
Juan Fernandez Petrel *Pterodroma externa*	--	--	--	--	--	--	A
Kermadec Petrel *Pterodroma neglecta*	--	--	--	--	--	--	C
Herald Petrel *Pterodroma heraldica*	--	--	--	--	--	--	F
Defilippe's Petrel *Pterodroma defilippiana*	--	--	--	--	--	--	A
Cook's Petrel *Pterodroma cooki*	--	--	--	--	--	--	F
Sooty Shearwater *Puffinus griseus*	F	--	--	--	C	A	A
Short-tailed Shearwater *Puffinus tenuirostris*	R	--	--	--	--	--	--
Pink-footed Shearwater *Puffinus creatopus*	--	--	--	--	R	R	--
Buller's Shearwater *Puffinus bulleri*	--	--	--	--	--	F	C
Wedge-tailed Shearwater *Puffinus pacificus*	--	R	R	--	--	--	--
Audubon's Shearwater *Puffinus lherminieri*	--	C	F	--	--	--	--
Elliot's Storm-Petrel *Oceanites gracilis*	--	--	--	--	A	A	A

Table 8.1 (cont.)

Leach's Storm-Petrel Oceanodroma leucorhoa	R	A	C	A	--	--	--
Band-rumped Strom-Petrel Oceanodroma castro	--	--	--	F	--	--	--
Wedge-rumped Strom-Petrel Oceanodroma tethys	--	--	R	A	F	--	C
Ashy Storm-Petrel Oceanodroma homochroa	F	--	--	--	--	--	--
Least Strom-Petrel Oceanodroma microsoma	--	C	--	--	--	--	--
Hornby's Storm-Petrel Oceanodroma hornbyi	--	--	--	--	R	A	A
Black Storm-Petrel Oceanodroma melania	--	R	--	--	R	R	--
Markham's Storm-Petrel Oceanodroma markhami	--	--	--	--	--	R	A
Fork-tailed Storm-Petrel Oceanodroma furcata	R	--	--	--	--	--	--
White-bellied Storm-Petrel Fregetta grallaria	--	--	--	--	--	--	R
Peruvian Diving-Petrel Pelicanoides garnoti	--	--	--	--	F	F	--
Red-billed Tropicbird Phatheon aethereus	--	F	--	R	--	--	R
Brown Pelican Pelecanus occidentalis	--	--	--	--	C	--	--
Peruvian (Brown) Pelican Pelecanus thagus	--	--	--	--	A	A	R
Masked Boobie Sula dactylatra	--	C	R	--	--	--	R
Red-footed Boobie Sula sula	--	C	A	--	--	--	--
Blue-footed Boobie Sula nebouxii	--	--	--	--	A	--	--
Brown Boobie Sula leucogaster	--	--	A	--	--	--	--
Peruvian Boobie Sula variegata	--	--	--	--	A	A	C
Guanay Cormorant Phalacrocorax bougainvillii	--	--	--	--	F	A	--
Magnificent Frigatebird Fregata magnificens	--	--	R	--	F	--	--
Northern Phalarope Phalaropus lobatus	F	A	--	R	C	--	--
Red Phalarope Phalaropus fulicarius	C	A	R	A	R	F	--
South Polar Skua Catharacta maccormicki	--	--	--	--	--	F	F
Chilean Skua Catharacta chilensis	--	--	--	--	--	F	F
Pomarine Jaeger Stercorarius pomarinus	R	C	F	--	A	A	R
Parasitic Jaeger Stercorarius parasiticus	F	R	--	--	C	C	--

Long-tailed Jaeger Stercorarius longicaudus	--	F	--	--	R	C	R
Kelp Gull Larus dominicanus	--	--	--	--	R	R	R
Herring Gull Larus argentatus	A	--	--	--	--	--	--
Western Gull Larus occidentalis	F	--	--	--	--	--	--
Glaucous-winged Gull Larus glaucescens	C	--	--	--	--	--	--
Band-tailed Gull Larus belcheri	--	--	--	--	--	R	--
Laughing Gull Larus atricilla	--	F	--	--	C	R	--
Franklin's Gull Larus pipixcan	--	--	--	--	A	A	--
Sabine's Gull Larus sabini	F	F	--	--	C	--	--
Swallow-tailed Gull Larus furcatus	--	--	--	--	R	R	--
Black-legged Kittiwake Rissa tridactyla	A	--	--	--	--	--	--
Sooty Tern Sterna fuscata	--	--	--	--	--	--	R
Royal Tern Sterna maxima	--	--	--	--	R	--	--
Common/South American Tern Sterna hirundo/hirundinacea	--	--	--	--	C	C	--
Inca Tern Larosterna inca	--	--	--	--	R	A	--
Peruvian Tern Sterna lorata	--	--	--	--	F	--	--
Black Tern Sterna niger	--	F	--	--	C	--	--
Least Tern Sterna antillarum	--	F	--	--	--	--	--
Tuffted Puffin Fratercula cirrhata	F	--	--	--	--	--	--
Rhinoceros Auklet Cerorhinca monocerata	R	--	--	--	--	--	--
Cassin's Auklet Ptychoramphus aleuticus	A	--	--	--	--	--	--
Parakeet Auklet Cyclorrhynchus psittacula	F	--	--	--	--	--	--

Table 8.2 Species of marine mammals seen by region and number. See Table 8.1 for denotation of abbreviated regions.

	NA	NI	CR	EC	NP	SP	NC
Dall's Porpoise *Phocoenoides dalli*	28	0	0	0	0	0	0
Bottlenose Dolphin *Tursiops truncatus*	0	150	0	0	30	0	15
Spinner Dolphin *Stenella longirostris*	0	80	0	0	0	0	0
Spotted Dolphin *Stenella* spp.	0	3	0	0	0	0	0
Striped Dolphin *Stenella coeruleoalba*	0	30	0	0	0	0	0
Common Dolphin *Delphinus delphis*	0	0	0	0	600	50	0
Dusky Dolphin *Lagenorhynchus obscurus*	0	0	0	0	0	25	0
Pygmy Killer Whale *Feresa attenuata*	0	8	0	0	35	0	0
Pilot Whale *Globicephala* spp.	0	0	0	0	33	11	0
Sei Whale *Balenoptera borealis*	0	0	0	0	0	2	0
Sperm Whale *Physeter macrocephalus*	0	0	0	0	14	0	0
South American Sea Lion *Otaria flavescens*	0	0	0	0	5	54	0

9. Operations and logistics at Seal Island, Antarctica, during 1992/93; submitted by J.L. Bengtson and R.V. Miller.

9.1 Objectives: The AMLR Program maintains a field camp at Seal Island, South Shetland Islands, Antarctica (60°59'14"S, 55°23'04"W), in support of land-based research on marine mammals and birds. The camp is occupied during the austral summer field season, which normally runs from December through March. The main logistics objectives of the 1992/93 season were:

1. To deploy the field team early in December aboard the M/V *Explorer* in order to arrive at Seal Island in time to monitor fur seal pupping and penguin chick hatching,

2. To deploy one additional field team member to assist in field studies in mid-January and recover two field team members in early February aboard the NOAA Ship *Surveyor*,

3. To resupply the field camp with its season's provisions, which were transported from the United States aboard the NOAA Ship *Surveyor*,

4. To maintain effective communications systems on the island and to maintain daily radio contact with either Palmer Station or the NOAA Ship *Surveyor*,

5. To repair, maintain, and improve camp facilities at the Seal Island field camp, and

6. To retrograde trash and other cargo from the island and to transport the field team to Chile at the end of the season aboard the NOAA Ship *Surveyor*.

9.2 Accomplishments: A five person field team departed the U.S. on 21 November and embarked the tour ship M/V *Explorer* in Stanley, Falkland Islands, on 24 November. After its trip south via South Georgia, the South Orkney Islands, and the South Shetland Islands, the ship arrived at Seal Island and disembarked the field team on 4 December. Good weather resulted in an efficient landing at the camp beach. Camp structures overwintered well and without damage. The main tent, which serves as the principal accommodation, was erected within 2 days of the team's arrival.

The NOAA Ship *Surveyor* arrived and offloaded cargo at Seal Island on 14 January. Cargo operations began in the morning, but had to be postponed by mid-day when high winds and rough seas precluded continuing. As in past seasons, two Mark V Zodiacs were used to transport supplies ashore. The assistance of ship's personnel and members of the scientific party expedited cargo operations. In addition to the persons who came ashore to help unload and carry cargo up to camp, four swimmers in dry suits were stationed to steady the Zodiacs during unloading. The sixth member of the Seal Island field team also came ashore during this visit. The remaining cargo was brought ashore on 21 January; this operation went very smoothly.

On 5 February, the NOAA Ship *Surveyor* returned to Seal Island and embarked two members of the field team to return to Chile. The *Surveyor* returned again to Seal Island on 17 February to offload fresh supplies purchased during an in port between Legs I and II.

Daily radio communications were maintained with Palmer Station from 4 December to 13 January prior to the arrival of the *Surveyor* in the operations area. Daily contact was maintained with the *Surveyor* from 13 January to 10 March, using single side-band or VHF radio when the ship was within radio range of the island. In addition to these regular schedules, radio contacts were made with biologists and other personnel at Palmer Station, Anvers Island (U.S.); Admiralty Bay camp, King George Island (U.S.); M/V *Explorer* (U.S.); R/V *Knorr* (U.S.); M/V *Polar Princess* (France); and King Sejong Station, King George Island (Korea). Communications were also maintained with various offices in the U.S. via the ATS-3 satellite system. No significant difficulties were experienced with any of the camp's communication systems.

Routine maintenance of camp facilities was undertaken as necessary. Obsolete and unneeded equipment was identified and removed from the island for shipment to the U.S. Wooden structures were painted and weatherproofed. A raised walkway was installed between structures in the main camp to keep personnel and equipment out of the ever-present mud. A solar panel array was installed to enhance the camp's direct current power system. This array is equipped with a tracking capability to follow the sun's movements, thereby optimizing the panel's position for generating power. A third solar panel array was installed above the new battery box attached to the lab. This two-panel array remains in place over the winter to provide charged batteries for the next field season.

During the initial resupply of Seal Island on 14 and 21 January, trash from the early part of the season was transported to the NOAA Ship *Surveyor* for proper disposal. Additional trash and retrograde cargo was transported to the *Surveyor* each time that the ship called at Seal Island throughout the season to minimize the amount of cargo necessary to offload at the end of the season. All remaining trash and cargo was loaded onto the ship on 10 March, when the camp was closed and the field team embarked the ship for transport to Chile.

9.3 Recommendations: Once again, the excellent support provided by the NOAA Ship *Surveyor* made a significant contribution to the success of the field season at Seal Island. Cargo and small boating operations went very smoothly. The practice of providing 4 swimmers in dry suits to assist landings and launchings of Zodiacs has proven to be very successful and should be continued in future seasons.

An arrival date of early December was ideal for initiating antarctic fur seal studies prior to the peak of pupping. If possible, arrival of the field team should be planned for the first week of December in future seasons as well. Such an arrival date provides good access to perinatal female fur seals as well as an opportunity to obtain data on fur seal females' early feeding trips before their pups fall prey to leopard seals.

10. Pinniped research at Seal Island during 1992/93; submitted by B.G. Walker, M.K. Schwartz, J.L. Bengtson and M.E. Goebel.

10.1 Objectives: In 1992/93, pinniped monitoring programs continued on Seal Island as part of the CCAMLR Ecosystem Monitoring Program (CEMP), a multi-national program designed to detect significant changes in key components of the Southern Ocean ecosystem and to distinguish between changes due to commercial fisheries and those due to natural causes. A major objective of this research is to determine what factors influence the population dynamics of antarctic pinnipeds. Current studies are focused on feeding ecology, reproductive success, growth and condition, demography and abundance, as well as the status of prey availability and other environmental conditions. During the 1992/93 field season, specific objectives of the pinniped research at Seal Island were:

1. To monitor antarctic fur seal (*Arctocephalus gazella*) pup growth rates and adult female foraging according to CEMP protocols,

2. To conduct directed research on fur seal pup production, female foraging behavior, diet, abundance, survival and recruitment,

3. To evaluate an automatic direction-finding system for determining the offshore foraging areas of fur seals, and

4. To monitor the abundance of all other pinniped species ashore.

10.2 Accomplishments:

Pup growth rates: Fur seal pups were weighed at approximately two week intervals throughout the field season, commencing when the pups were approximately 1 month old: from 30 December to 25 February (CEMP Standard Method C.2) (Table 10.1). Male pups increased in mass at a rate of 134.6 grams per day (SE = 5.7g), while females increased at a rate of 100.6 grams per day (SE = 4.5g). Bi-weekly mean estimates for both sexes in the 1992/93 season were lower than those recorded in the 1991/92 season by 0.5-1.5kg.

Foraging behavior and attendance ashore: Estimation of female trip duration, CEMP Standard Method C.1, specifies that only the first six feeding trips are to be used in calculation of the female foraging duration. Female fur seal attendance duration on Seal Island was monitored using radio-transmitters (CEMP Standard Method C.1). During the perinatal period, after parturition and prior to their first trip to sea, 40 female fur seals were instrumented with radio transmitters (7 December to 13 December). At-sea trip duration and time ashore were recorded on data-logging computers. Twenty-one of the 40 females instrumented completed six trips to sea without losing a pup. The mean duration of all foraging trips for these 21 females was 107.2 hours (SD = 45.5; n = 126) (Table 10.2).

In the 1992/93 season, mean trip duration was greater than averages recorded in the 1991/92 season for all of the first six trips, with the exception of trip 1, which was approximately 2.7 hours longer than the mean of trip 1 in 1992/93 (Table 10.2).

Fifteen females in the foraging trip/attendance studies were also instrumented with time-depth recorders (TDR's) to document diving behavior as a measure of foraging effort expended by females while at sea. Fourteen of the 15 TDR's were recovered and these dive records will be analyzed at the National Marine Mammal Laboratory (NMML) in Seattle.

Pup production: Pups (both alive and dead) were counted daily at the North Cove and North Annex colonies to determine the maximum number of births in the main breeding areas. The maximum number of live pups at North Cove was 213 on 21 December. At North Annex, a maximum of 75 live pups was recorded on 30 December. Including a count of 4 pup carcasses in these two colonies prior to 30 December, pup production was estimated to be at least 292 individuals for the major breeding colonies on Seal Island.

In addition to the main breeding colonies at North Cove and North Annex, the small breeding colony (Big Booté) on the remote east side of the island was censused periodically to estimate pup production. On 27 December, 14 pups were recorded in this colony.

As in each of the previous six field seasons, a census of the breeding colony of fur seals on Large Leap Island (1km north of Seal Island) was conducted. The colony there is similar in size to the colony at North Cove and is censused annually for comparative purposes between disturbed and non-disturbed colonies. On 21 January 1993, 304 pups were counted on this rookery, an increase of 46 pups over the total counted the previous field season.

Abundance, survival and recruitment: Because the pup cohort is the only age class to remain entirely ashore during any particular census period, the number of pups produced yearly provides the best comparative estimate as to colony size between years. The maximum number of pups counted at North Cove in 1992/93 (217: 213 live, plus 4 dead) decreased from the 233 pups counted at the peak of the 1991/92 season. In contrast, North Annex showed an increase in pup production: maximum count this year of 75 pups as compared to the maximum 1991/92 count of 58 pups. Big Booté colony remained unchanged from last year, with 14 pups again estimated from this small colony. The sum total of pups in the three breeding areas for this year, 306 individuals, is very close to the number of pups estimated in the same three breeding areas in the 1991/92 season (304 individuals).

Leopard seal (*Hydrurga leptonyx*) predation was directly observed on three occasions this season. Although only nine pups were observed to be taken by leopard seals (five on 31 December, three on 3 January; one on 18 January), marked decreases in pup numbers corresponding to the periods when leopard seal predation was observed may imply that this predation is a significant factor in the mortality of pups in North Cove. In contrast to North Cove, North Annex appears to be sheltered from leopard seal predation by its more shallow and hidden entrances. North Annex did not have corresponding decreases in pup numbers in the same periods as those observed for pups in North Cove.

All classes of fur seals present on Seal Island were censused at approximate weekly intervals along the accessible coastline from Beaker Bay beach up to and including North Cove. Besides pups, fur seals were classified as females, adult males with females, adult males without females, subadult males, and juveniles of undetermined sex. The total fur seal population increased throughout the season, with numbers on the final census day, 3 March, reaching approximately 1,427 individuals in all age and sex categories (Table 10.3). In comparison, maximum fur seal population estimates for the 1991/92 season were taken on 18 February 1992, with 1,064 individuals in the various age and sex categories being recorded as present on Seal Island.

Daily observations of tagged female fur seals were conducted to estimate survival, reproductive rates, and tag loss. Of the 127 tagged females observed in the 1991/92 season, 110 were observed again this year, 94 of which were observed to have produced a pup. Of the 40 females with radio transmitters in the 1991/92 season, 33 were observed again on Seal Island this season. Twenty-eight of these 33 were observed with pups. In the course of instrumentation studies, twenty-five new tags were placed on adult females of unknown age this year. This total includes two females which were re-tagged with new All-flex tags due to the loss of one tag previously administered.

In the 1992/93 season, only one fur seal not tagged at Seal Island was seen; a sub-adult male observed on Beaker Bay beach with a blue Rototag. However, no number or other information was readable from this tag.

Along with the tagging of adult females in instrumentation studies, tagging of pups present at both North Cove and North Annex has been undertaken every year on Seal Island since 1986/87. A total of 55 known-age individuals were observed on Seal Island this season (Table 10.4). In the 1992/93 season, 166 additional pups (88 female, 78 male) were tagged with rounded-post monel flipper tags.

Diet: Fur seal feces were collected at bi-weekly intervals. Each sample consisted of eight to ten scats from each sex. The scats were put in frozen storage on board *Surveyor* for subsequent analysis of prey remains at NMML.

Offshore foraging areas: As part of a new automatic direction-finding (ADF) system being tested on Seal Island in the 1992/93 season, three female fur seals were instrumented with specialized rapid pulse emitting radio transmitters. In future seasons, this ADF system will be used to determine the bearing from Seal Island of a foraging seal carrying a transmitter and will be instrumental in monitoring foraging locations of both seals and seabirds (see accompanying report on Seal Island seabird research for more information).

Abundance of other pinniped species: Along with the weekly census of total fur seal numbers, counts were made of other pinniped species that use Seal Island as a hauling area. Other species observed were southern elephant seals (*Mirounga leonina*) and Weddell seals (*Leptonychotes weddelli*) (Table 10.5). As previously mentioned, leopard seals were observed on and around Seal Island, but none were seen hauled out on any pinniped census day.

Fur seal entanglements: A minimum of ten different fur seals were observed entangled with man-made debris in 1992/93. Most of the material consisted of either loops of multiple-fiber plastic packing bands, or pieces of fishing line of various thicknesses and lengths. All of the fur seals found entangled were males of various sizes and ages. All debris was limited to the upper body above the foreflippers and typically seen around the mid to upper neck of the seals.

10.3 Tentative conclusions: Measurements of pup production and growth seem to indicate that the 1992/93 season was typical with respect to fur seal's ability to obtain prey and nourish offspring. Continued analysis of female foraging behavior, both from data-logging computer files and TDR records, will allow further conclusions to be drawn as to the success of the pinniped populations for the breeding season of 1992/93. Also, comparisons of fur seal success rates with data on krill abundance and other oceanic factors, both in this and previous years, will enhance our ability to predict the way in which pinniped species are affected by the changes in their surrounding environment.

Table 10.1 Mean weights, standard deviations, and sample sizes of male and female fur seal pups weighed during five sampling intervals, 30 December 1992 - 25 February 1993.

	Sampling dates				
	30 Dec.	13 Jan- 14 Jan	26 Jan- 28 Jan	10 Feb- 12 Feb	24 Feb- 25 Feb
MALES:					
mean wt. (kg)	8.73	10.28	12.93	14.87	15.97
std.dev.	1.67	1.73	1.86	1.82	1.70
n	42	57	45	43	55
FEMALES:					
mean wt. (kg)	7.55	8.98	10.86	12.16	13.05
std.dev.	1.27	1.46	1.67	1.37	1.46
n	58	43	55	56	46

Table 10.2 Mean duration of trips, standard deviation, sample size, maximum and minimum trip lengths for the first six trips to sea for 21 female fur seals with pups at North Cove, Seal Island, 1992/93.

Trip #	Mean (h)	St. dev.	Maximum (h)	Minimum (h)	N
1	98.40	53.7	238.8	35.9	21
2	124.47	38.0	198.2	28.6	21
3	119.84	43.5	222.6	8.5	21
4	120.40	50.9	222.2	6.7	21
5	107.88	26.6	158.9	63.3	21
6	72.07	37.9	127.2	8.8	21
ALL	107.17	45.5	238.8	6.7	126

Table 10.3 Weekly counts of antarctic fur seals, by sex and reproductive status, at Seal Island, Antarctica, 1992/93. These counts were made in a standard census area (which excludes the small fur seal rookery at Big Booté on the north side of the island).

Date	Pups	Adult females	Adult males with females	Adult males without females	Subadult males	Juveniles
9 Dec	185	160	32	59	5	0
12 Dec	253	169	28	54	4	0
22 Dec	273	120	27	69	8	0
29 Dec	258	117	28	49	17	0
5 Jan	214	116	24	43	12	0
13 Jan	205	90	14	9	19	0
19 Jan	202	171	12	18	67	0
26 Jan	168	126	10	5	209	0
2 Feb	159	190	24	34	398	0
11 Feb	139	192	9	74	395	5
19 Feb	146	210	9	83	495	40
23 Feb	144	230	0	132	760	32
2 Mar	142	229	0	113	891	52

Table 10.4 Numbers of known-aged fur seals observed on Seal Island, 1992/93.

Cohort	Males	Females	Total
1986/87	1	1	2
1987/88	9	5	14
1988/89	5	6	11
1989/90	1	1	2
1990/91	7	3	10
1991/92	13	3	16

Table 10.5 Weekly counts of pinnipeds other than antarctic fur seals at Seal Island, Antarctica, 1992/93 (these counts reflect those seals hauled out at the specific time of the day's census).

Date	Elephant Seals	Weddell Seals	Leopard Seals
9 Dec	12	4	0
12 Dec	25	4	0
22 Dec	33	2	0
29 Dec	32	3	0
5 Jan	23	2	0
13 Jan	14	0	0
19 Jan	14	1	0
26 Jan	23	0	0
2 Feb	16	0	0
11 Feb	24	2	0
18 Feb	12	0	0
23 Feb	8	1	0
2 Mar	6	0	0

11. Seabird research at Seal Island, Antarctica during 1992/93; submitted by John K. Jansen, William R. Meyer, J.L. Bengtson, and Donald A. Croll.

11.1 Objectives: Seabirds have been shown to serve as useful monitors of offshore prey resources. This is particularly true during the breeding season when the birds must return to their nest sites, limiting the area over which the birds may forage. In addition, the presence of birds on their breeding sites provides access for investigators to monitor various aspects of breeding and foraging that can serve as indices of offshore prey availability. Five seabird species breed on Seal Island: chinstrap penguins (*Pygoscelis antarctica*), macaroni penguins (*Eudyptes chrysolophus*), cape petrels (*Daption capensis*), Wilson's storm petrels (*Oceanites oceanicus*), and kelp gulls (*Larus dominicanus*). Southern giant petrels (*Macronectes giganteus*) and blue-eyed shags (*Phalacrocorax albiventer*) breed on adjacent islands. Penguins are particularly useful for monitoring purposes. During the breeding season they are tied to one location ashore where they return repeatedly throughout a 4 to 5 month period. Being flightless seabirds, they are further limited in the distance they are able to forage from the breeding site. Therefore, aspects of their behavior and ecology reflect biotic and abiotic conditions adjacent to their land-based breeding areas.

As part of the U.S. AMLR program's participation in the CCAMLR Ecosystem Monitoring Program (CEMP), Seal Island was chosen as one of two sites in the Antarctic Peninsula region for the study of krill-consuming seabirds. The principal research objectives for the 1992/93 field season were:

1. To monitor the breeding success, fledgling size, reproductive chronology, foraging behavior, diet, abundance, survival, and recruitment of chinstrap and macaroni penguins according to CEMP protocols,

2. To examine penguin chick growth and condition for intra- and inter-seasonal comparisons,

3. To conduct directed research on seasonal and diel patterns in the diving behavior of chinstrap penguins in order to assess changes in foraging patterns and effort as physical and biological components change through the breeding season,

4. To examine intra-seasonal changes in penguin chick provisioning contemporaneously with foraging effort,

5. To test an automatic direction-finding system for monitoring the locations of offshore foraging areas of chinstrap penguins, and

6. To assess the reproductive success, survival, and recruitment of cape petrels.

11.2 Accomplishments:

Reproductive success and chronology: Breeding success was estimated according to CEMP Standard Methods A.6.B. (observations of 100 nest plots) and A.6.C. (discrete counts of colonies). Method A.6.B. is designed to determine the number of chicks raised to the creche stage for a set of nests. Rectangular plots of individually-identified chinstrap nests each were marked by stakes in 2 colonies (130 and 117 nests in the North Cove and Parking Lot study plots, respectively). Thirty macaroni penguin nests at Mac Top colony were also identified of which 27 were monitored. These nests were observed every other day from a blind using a spotting scope (without entering the colony), and the number of incubated eggs and/or brooded chicks was recorded. Overall, of the chinstrap nests active at the commencement of observations (13 and 15 of December for the Parking Lot and North Cove plots, respectively), a total of 1.3 chicks/active nest were raised to creching at the Parking Lot plot.

These plots were also used to determine the chronology of penguin reproductive events at Seal Island through creching (Table 11.1). Chinstrap hatching began on 21 December, while the rate of hatching peaked on 27 December and 1 January, and was completed by 24 January and 28 January in the Parking Lot and North Cove study plots, respectively. Creching began 25 January at both Parking Lot and North Cove colonies, although data indicate a slower rate of creching at North Cove.

Hatching of macaroni chicks began on 24 December, hatching rate peaked around 27 December, and was completed by 12 January. Macaroni creching began on 18 January and was completed by 30 January. Fledging began on 19 February and was completed on 26 February. The number of macaroni chicks/active nest raised to creching at Mac Top was 0.85, while 20 of these chicks survived to fledging, giving a fledging success rate of 0.77 fledglings/active nest.

Upon completion of creching, the number of creched chinstrap chicks was counted every other day in colony 66 (a colony of about 300 nests) to provide an estimate of the progression of fledging. Fledging began on 13 February, the fledging rate peaked around 19 February, and was completed by 8 March.

Foraging behavior: The duration of foraging trips was monitored to determine the amount of time at sea required by breeding adults to meet their own energetic needs and procure food for chicks, serving as an indicator of foraging effort and prey availability (CEMP Standard Method A.5.). A total of forty adult chinstrap penguins was equipped with radio transmitters (40 nests with one member of each nest equipped with transmitters) to monitor their presence ashore. An automatic scanning radio receiver and data logger recorded the attendance of radio-tagged birds every fifteen minutes. Nests of instrumented birds were checked regularly for survival of chicks in an effort to exclude data from failed nests from subsequent analysis.

To provide detailed information on chinstrap penguins' diving behavior at sea, and how that behavior may change with the progression of the breeding season, a total of 49 chinstrap penguins were equipped with time-depth recorders (TDRs) which recorded depth while diving, time spent at the surface between dives, and time ashore: 14 during incubation, 15 during the early guard stage, 10 during the late guard stage, and 10 during the creche stage. Of these deployments, 47 records were obtained. The dive records will be analyzed at NMML to estimate foraging effort within and between seasons.

Diet: As important predators of marine resources, penguins can serve as samplers of the offshore marine environment from which their ability to produce offspring depends. The diet of breeding penguins can reflect the short-term and long-term fluctuations in the availability of prey adjacent to the breeding colonies. In an effort to shed light on the relationship between available food offshore and prey brought back to the colonies to provision offspring, a total of 35 stomach content samples was collected from breeding chinstrap penguins between 11 January and 4 February 1993 (CEMP Standard Method A.8.). The sampling schedule was divided into seven 5-day collection periods. Adult birds were captured immediately upon returning to the colony after feeding trips to sea. These birds were weighed, measured (bill length, bill depth, and wing length), and banded prior to sampling. Stomach samples were obtained by lavaging with warm water. Prior to being released, the birds were dyed with a yellow picric dye (to ensure that the bird was not handled again during the season).

The protocol for sampling was modified this year in an effort to examine diurnal changes in foraging behavior and prey abundance. Diet samples were taken from two study groups of breeding chinstrap penguins: (1) birds returning from night and early morning foraging trips, and (2) birds returning from daytime foraging trips. As in past seasons, preliminary analyses have indicated krill as the major prey species in both study groups. Interestingly, more evidence of fish prey was discovered in diet samples taken from birds feeding nocturnally. Sixty-percent of all samples (N=15) taken from nocturnal/early morning foragers revealed evidence of fish. In contrast, only ten-percent of the samples (N=20) taken from diurnal foragers had evidence of fish. Samples were sorted to remove otoliths and other prey hard parts in preparation for preservation and transport to NMML for further detailed analysis.

Abundance, survival, and recruitment: The number of breeding pairs in all penguin colonies on the island was counted. The census was made after the completion of egg laying. The timing of this count was estimated due to the teams arrival on the island after the birds had begun laying. Due to logistical limitations, the field team has arrived after the initiation of egg-laying in all past seasons. For this reason, the latest historical arrival (17 December) was deemed the most useful date for comparative purposes to count the number of active nests. All birds lying down in some sort of nest structure were assumed to be occupying a nest site and were thus considered breeding. Large colonies (3, 4, 14, 25, 26, 58, and 61) were counted from photographs. The total number of chinstrap pairs nesting in 1992/93 was estimated at 21,717. This number is approximately 4% less than the number of birds counted the previous year. A total of 266 pairs of macaroni penguins attempted to breed on Seal Island in 1991/92, 5% more nests than recorded the previous year.

According to CEMP Standard Method A.6.C., three censuses were made of 10 geographically discrete chinstrap penguin colonies (9, 21, 24, 31, 32, 33, 42, 51, 54, and 66) undisturbed by other activities. The number of nests with incubated eggs was counted near our arrival date, some time after laying was complete. When hatching was complete, the number of nests with chicks and the number of chicks in each nest was counted. When creching was complete, the total number of chicks in each colony was counted. Three replicate counts were made of each colony on the same day. If one of the three counts differed by more than 10% of any other count, a fourth count was made. The mean and standard deviation of the three (or four) counts was computed as an estimate of the parameter. Each of the five macaroni penguin colonies was also censused. Data from the past four seasons of chinstrap penguin censuses are summarized in Figure 11.1.

To estimate annual survivorship and recruitment into the breeding population, 2,000 chinstrap and 76 macaroni penguin chicks were banded. By resighting banded birds in subsequent years, an estimate of age specific annual survival and recruitment can be calculated. Both systematic and opportunistic surveys to resight banded birds were conducted throughout the season.

Growth and condition: To provide another index through which to compare environmental conditions between and within seasons, the monitoring of growth rates of chinstrap penguin chicks was conducted for the sixth consecutive year. Data on chick growth were collected by measuring the weight, culmen length, culmen depth, wing length, and noting the status of juvenile plumage molt every 5 days for 8 time periods between 6 January and 20 February at colony 4. Prior to creching, chicks numbering no less than 50 (contained in at least 30 nests) were measured during 5 sampling periods. After creching, a total of 75 chicks was measured per sampling period. After handling, chicks were dyed to avoid sampling them more than once during the season. Mean chinstrap chick weight peaked at 3.38kg on 15 February (Figure 11.2).

Following the initiation of chinstrap penguin fledging on 13 February, daily samples of fledglings present on Beaker Bay were weighed (CEMP Standard Method A.7.A.) until the completion of fledging, about 8 March. A total of 293 fledglings were weighed and measured. Average (± sd) fledgling measurements were: weight 3.08kg (±0.35); culmen length 43.27mm (±2.82); culmen depth 14.57mm (±0.98); and wing length 110.12mm (±5.56).

Macaroni chick weight, culmen length, culmen depth, and wing length were measured, and the status of juvenile plumage molt was noted when banding chicks on 17 and 18 February. Morphometric data collected on these dates will provide a comparison of chick condition prior to fledging for all past years. Mean (± sd) weights at this time were 3.36kg (±0.322); culmen length and depth were 45.36mm (±3.15) and 17.67mm (±1.65), respectively; while mean wing length was 100.47mm (±4.45).

Food load delivery to chicks: Diving behavior and diet of chinstrap penguins breeding on Seal Island have been monitored each year on Seal Island since 1987. These data have provided an estimate of foraging effort and prey composition. In an effort to correlate these parameters with prey capture rates, the amount of food delivered to chicks was measured through continuous monitoring of nest mass. When coupled with diving behavior and diet, this information will significantly add to an assessment of the prey requirements and catch per unit effort of chinstrap penguins.

The study was initiated during two phases of the penguin's chronology: incubation and early guard. Three nests were monitored during each phase of the study. The weight of adults returning to their nest to feed their young and the weight of birds departing to feed was manually recorded throughout the observation period.

The weighing system consisted of three waterproof electronic scales each having a hundred feet of cable. These units were placed underneath existing chinstrap penguin nests. The nests were temporarily displaced, a small area was excavated, and the scales with a simulated nest surface were placed in the excavated area. The eggs or chicks were replaced on the new surface. Each nest was connected to a central data display located within the Parking Lot colony observation blind. The mass of each of the nests was logged every 30 minutes or upon arrival or departure of adults. The nest mass, offspring, and adult attendance was continuously monitored visually from the blind for a period of approximately 5 days or until data on two arrivals and two departures were collected from each member of the pairs.

Both adults of each nest were equipped with dive recorders. This will allow a measurement of daily foraging effort to be correlated with mass of food delivered to the nest. The results of these measurements will be analyzed at the National Marine Mammal Laboratory in Seattle.

Offshore foraging areas: An important component of understanding penguin foraging ecology is knowing the locations of their principal offshore feeding areas. Time-depth recorders have been used successfully to provide information about the vertical distribution of prey resources, but obtaining data on the horizontal distribution of prey has been difficult. Previous efforts have included radio-tracking penguins from research vessels, but such operations are expensive and logistically inefficient. This season we ran tests on a land-based automatic direction-finding (ADF) system that was designed to indicate the general offshore locations where birds were foraging. The system monitored the relative compass bearing of signals from radio frequency transmitters that had been attached to the penguins. Some problems (mainly in the hardware) were encountered during the tests; however, preliminary indications are that this system may be able to monitor the location of penguins feeding up to 10 n.mi. offshore. If that objective can be achieved, it would allow analysis of how foraging areas change within and between seasons, and how these locations compare to the distribution of krill as estimated by acoustic surveys. The tests run this season were encouraging, and it is planned that development and testing of the ADF system will continue next year.

Cape petrels: The breeding success of 95 accessible cape petrel nests was estimated by surveying nests 5 times during the season, approximately every two weeks. The status of nests was recorded (occupied but empty, unoccupied and empty, incubated egg, attended chick, or unattended chick). Nesting success was estimated at 0.82 chicks/active nest on 2 February. A total of 76 petrel chicks were banded, weighed, and measured: mean weight (±sd), 540g (±84); culmen length, 30.20mm (±2.34); culmen depth, 8.14mm (+0.44); wing length, 209mm (±25). Material regurgitated by chicks during banding indicated that most chicks were being fed krill.

11.3 Preliminary conclusions: Similar to last season, census data indicate that the 1992/93 season was a very good year for recruitment of chinstrap penguins. Increased numbers of penguins attempting to breed could indicate a pre-season prey availability that was sufficient to allow more birds to achieve breeding condition. Despite this, relatively low hatching success occurred (only 72% of eggs present upon our arrival hatched, the lowest recorded compared to all past seasons). In contrast, of those chicks that hatched, 92% survived to creche (the highest recorded compared to all past seasons). These two extremes in survivorship when combined over the entire period of post egg-laying to creche result in a total survivorship comparable to past seasons (67%), except for the 1990/91 season which had the poorest breeding success recorded (59%). It is important to note that a significant portion of the penguins' life history is missing from our data due to the timing of the field team's arrival at Seal Island. Not having data on nest failure and egg mortality prior to our arrival would tend to overestimate breeding success. During this season and 1991/92 there was a higher proportion of two chick nests surviving to creche (1.6 chicks/nest), again indicating a greater ability to provide food to the chicks during most of the guard phase than in previous seasons.

The timing of initiation and peak of hatching was comparable to the previous two seasons (1989/90 was advanced by approximately three days). Even though the initiation of creching was delayed approximately four days, the peak occurred earlier and the progression was more accelerated than the previous two seasons. The synchronized timing of creching in the present season (and 1989/90) could be linked to an increased availability of food. Higher prey concentrations could support a wider range of successful foraging strategies and limit the variability in chronology. The beginning of fledging was almost a week earlier than last year, but the peak of fledging was within one day of all previous years except 1990/91, which was delayed approximately six days. It is difficult to determine what factors may have contributed to the early initiation of fledging this season. There is no evidence that chick development was more rapid compared to last year.

The increased chick survival observed during the period of provisioning would appear to reflect an enhanced ability to procure food. Several observations of enormous flocks (>1000) of chinstraps foraging between 11-14 January in areas between Seal Island and Elephant Island seem to substantiate successful provisioning of offspring during early to mid-guard phase. In fact, on 14 January many penguins were seen foraging within fifty meters of shore while large numbers of krill washed ashore. Although foraging during most of the brood phase appeared optimal, the early timing of creching and fledging might indicate a sudden decline in prey availability late in the guard phase. Creching signals the point where parents begin optimizing their foraging by feeding simultaneously in response to the increased demands of growing chicks. A limitation on their ability to find prey during late guard and creche might evoke a sudden shift in foraging strategy. Adjusting the timing of these events might be a potential mechanism for dealing with unpredictable changes in the environment. It would appear the costs associated with leaving chicks unattended (i.e.; predation, thermoregulation) reach a minimum well before creching usually occurs.

Breeding success (chicks surviving to creche) of macaroni penguins was the highest recorded compared to all past seasons. Fledging weight was also the highest recorded, indicating a successful season for this species as well. The initial breeding population was up from last year but down compared to the previous two seasons (1989/90 and 1990/91).

The number of cape petrels attempting to breed in accessible areas of the island continues to increase since the initiation of studies in 1987/88. Reproductive success of cape petrels (0.90 chicks/nest) was the second highest recorded (1991/92 was highest at 0.93 chicks/nest). Interestingly, chick mass at fledging was the lowest compared to the past three seasons, but other morphometric measurements (bill length, depth, wing chord) were the highest. It is possible that their chronology was further advanced compared to past seasons and their body mass had peaked prior to our measurements.

11.4 Recommendations: The physical and biological variability of the offshore environment necessitates an adaptable predator approach to finding and pursuing prey. Directed research on how offshore environmental components influence the detection and pursuit of prey would enhance the understanding of the predator's role in the ecosystem.

Table 11.1 Nesting chronology of chinstrap penguins at Parking Lot study plot on Seal Island, 1989/90 through 1992/93.

	1989/90	1990/91	1991/92	1992/93
Start hatching	20 Dec	23 Dec	20 Dec	20 Dec
Peak hatching	23 Dec	26 Dec	27 Dec	27 Dec
Start creching	20 Jan	22 Jan	23 Jan	25 Jan
Peak creching	22 Jan	30 Jan	31 Jan	28 Jan
Start fledging	5 Feb	16 Feb	19 Feb	13 Feb
Peak fledging	21 Feb	28 Feb	21 Feb	22 Feb

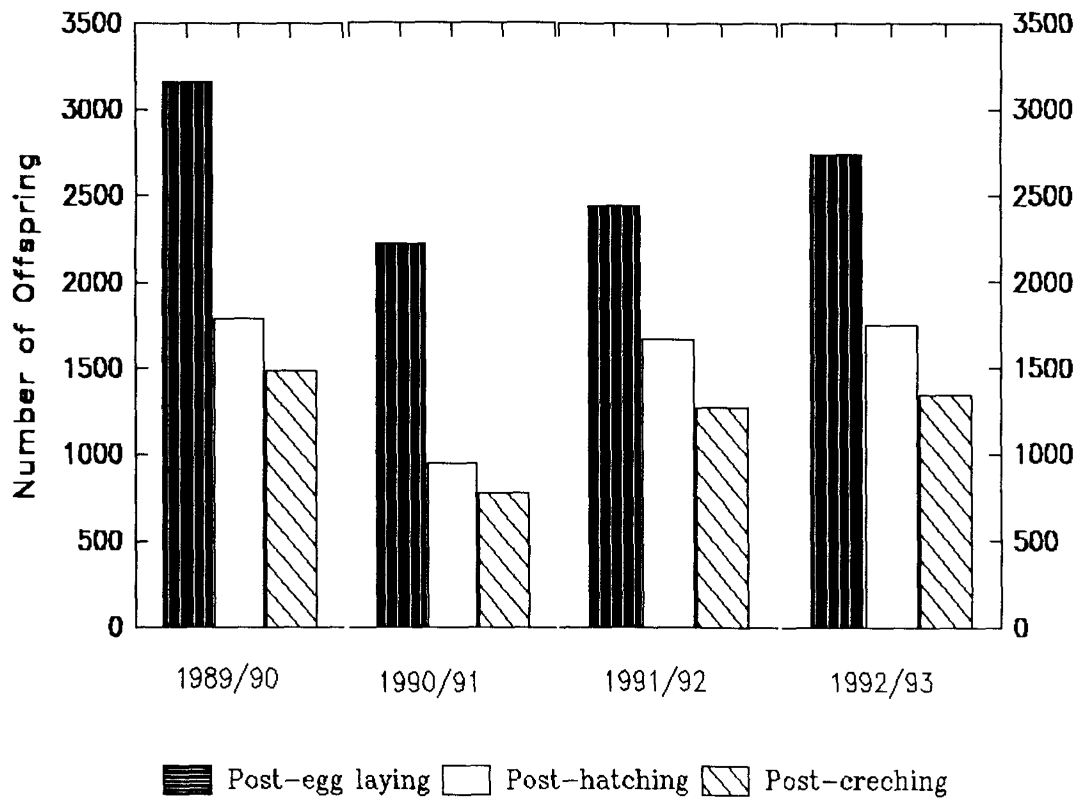
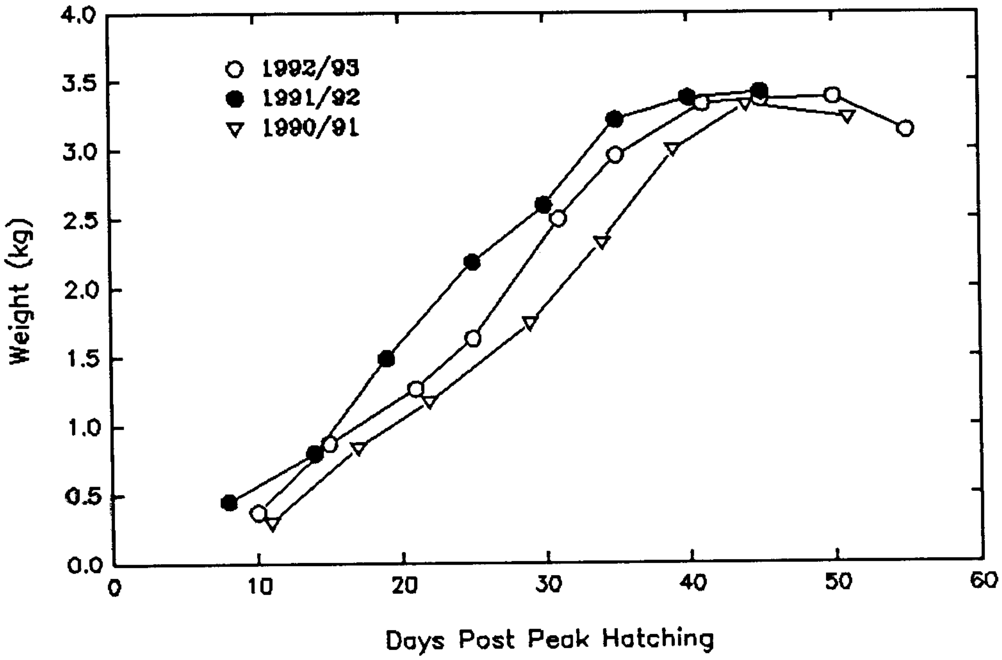


Figure 11.1. Number of chinstrap penguin offspring surviving to completion of laying, completion of hatching, and completion of creching at nine selected colonies on Seal Island, 1989/90 through 1992/93. Data for completion of egg-laying were collected upon arrival at the field camp in December and therefore does not take into account mortality that might have occurred between actual egg-laying and the census date.



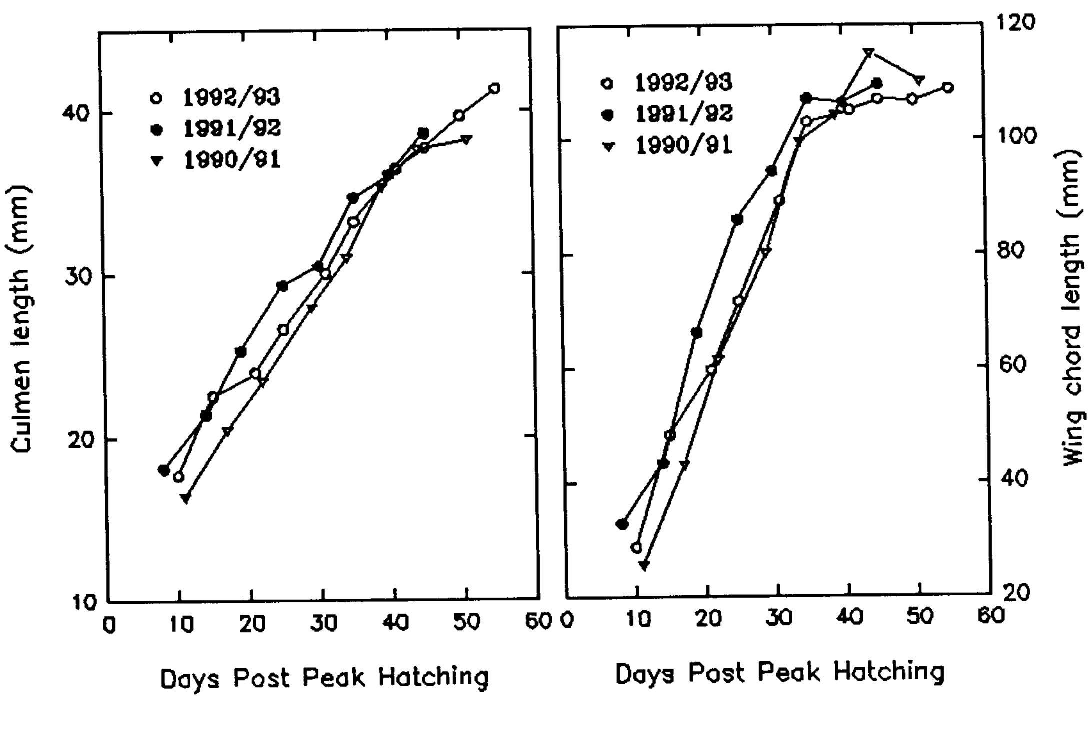


Figure 11.2 Growth parameters of chinstrap chicks at Parking Lot site on Seal Island, 1990/91 through 1992/93.

12. Seabird research undertaken as part of the NMFS/AMLR ecosystem monitoring program at Palmer Station, 1992-1993; submitted by William R. Fraser and Wayne Z. Trivelpiece.

12.1 Objectives: Palmer Station is one of two sites on the Antarctic Peninsula where long term monitoring of seabird populations is being undertaken in support of U.S. participation in CEMP. Our objectives during 1992-93, the sixth season of field work at Palmer Station, were:

1. To determine Adelie penguin breeding success,
2. To examine how present and past indices of Adelie penguin breeding success relate to a true measure of breeding success,
3. To obtain information on Adelie penguin diet composition and meal size,
4. To determine Adelie penguin chick weights at fledging,
5. To determine the amount of time breeding adult Adelie penguins need to procure food for their chicks,
6. To band a representative sample (1000 chicks) of the Adelie penguin chick population for future demographic studies,
7. To determine adult Adelie penguin breeding chronology, and
8. To continue exploring the feasibility of adding more of the Standard Methods to the suite of data now being collected at Palmer Station.

12.2 Accomplishments: Field work at Palmer Station was initiated on 6 October 1992 and terminated on 1 April 1993. The early start date was again aided by joint funding from the National Science Foundation's (NSF) Division of Polar Programs. NSF recently chose Palmer Station as a Long Term Ecological Research (LTER) site, and it has committed long-term funding and logistics support to an ecosystem study in which Adelie penguins represent one of two key upper trophic level predators selected for research. As a result of this cooperative effort between the National Marine Fisheries Service (NMFS) and NSF, field season lengths at Palmer Station now cover the entire 5-month Adelie penguin breeding season.

Until last season, breeding success in Adelie penguins had been estimated by using indices based on chick production per colony, the number of active nest sites in early January, and the ratio of 1-and 2-chick broods (see below). A true measure of breeding success, that is, the number of chicks reaching creche age per breeding pair, had not been previously obtained due to the late start of the field season and the subsequent inability to determine the number of breeding pairs and the fate of their eggs and chicks early in the season. This season we again followed a 100-nest sample on Humble Island from clutch initiation to creche. Adelie penguins again exhibited high reproductive success, creching 1.46 chicks per pair.

As in past seasons, two indices of breeding success were also examined. On 6 January, the proportion of 1 and 2 chick broods was assessed at 54 colonies in 5 different rookeries; on 26 January these and other colonies were censused to assess chick production. Production at these colonies totaled 7319 chicks, of which a sample of 2687 active territories fledged 4534 chicks. This suggests a per-pair productivity of 1.69 chicks, 0.23 chicks more than the more accurate measure of breeding success obtained above. This difference, which is consistent with figures obtained last season, is not large enough to negate the potential usefulness of these breeding success indices. This season, 60.2% of the territories examined contained 2-chick broods, a decrease of 10.3% over last season.

Diet studies were initiated on 11 January and terminated on 19 February. During each of the 8 sampling periods, 5 adult Adelie penguins were captured and lavaged (stomach pumping using a water off-loading method) as they approached their colonies to feed chicks on Torgersen Island. All birds (N=40) were subsequently released unharmed. The resulting diet samples were processed at Palmer Station. A nearly complete absence of all prey other than krill (*Euphausia superba*) characterized the 1992-93 samples. These krill were smaller than in previous seasons, averaging 35-40mm in length.

Adelie chick fledging weights (N= 322) were obtained between 5-23 February at beaches near the Humble Island rookery. Peak fledging occurred on 13 February, 6 days prior to last season; the average fledgling weight was 3.2kg.

Radio receivers and automatic data loggers were deployed at the Humble Island rookery between 13 January and 13 February to monitor presence-absence data on 40 breeding Adelie penguins instrumented with small radio transmitters. These transmitters were glued to adult penguins feeding 10-14 day old chicks. Analysis of the data has not yet been accomplished due to the size of the databases obtained. These results will be presented as part of the final report being delivered at a later date.

One-thousand Adelie penguin chicks were banded on 3 February as part of long-term demographic studies at AMLR colonies on Humble Island. The presence of birds banded in previous seasons was also monitored during the entire field season on Humble Island as part of these demographic studies.

A 100-nest sample was established on Humble Island to assess the chronology of breeding events, with relevant data being obtained every 1-3 days as weather permitted from 6 October to 1 April. Relative to last season, peak activity in a variety of breeding events occurred 6-10 days earlier. Variability between colonies was again evident and appeared to be correlated with snow cover present early in the breeding season.

Because of the longer field seasons being undertaken at Palmer Station, great potential exists for adding more of the CEMP Standard Methods to the suite of data being collected. In 1991-92, we successfully added Procedure B (chicks raised per breeding pair) to Standard Method A6.2 (breeding success). Procedure B, perhaps the most labor intensive of all the Standard Methods, was continued during 1992-93 to complement data being obtained with Procedure A (chick counts) and the proportion of 1- to 2-chick broods. This was also true of Standard Method A3.2 (breeding population size). Due to early season problems with access to the rookeries due to wind and pack ice, we again found it impossible to implement Procedure C (chicks raised per colony) and Standard Method A2.2 (duration of the first incubation shift). Data collection was again expanded to incorporate the months of October, November and December, which included weather and other environmental data as well.

12.3 Disposition of the Data: No diet samples were returned to the U.S. for analysis as all work was successfully completed at Palmer Station. All other data relevant to this season's research is currently on diskettes in our possession and will be made available to the Antarctic Ecosystem Research Group coincident with the final report on this season's activities due in July.

12.4 Tentative Conclusions: Adelie penguin breeding success was again high during 1992-93, but not significantly higher relative to the 1991-92 season (1.46 vs. 1.39 chicks creched/pair). Although the number of 2-chick broods present decreased, on average, by 10.3%, the overall number of chicks produced at 54 sample colonies was 7319, a 14.5% increase over last season. The factors responsible for this change are currently not known and must await further analysis of our data. As last year, the predominant component in the diets of Adelie penguins was the krill *Euphausia superba*. However, unlike last season, more krill in the smaller size classes dominated the diet samples (35-40mm vs. 45-50mm). We currently cannot provide any information on the relative availability of krill between seasons based on the telemetry data used to estimate the length of foraging intervals; analysis of these data is currently beyond the scope of this report due to the large size of the pertinent databases.

Mean Adelie penguin chick fledging weights did not differ significantly from those evident last season (3.20 vs. 3.20kg.). As last year, the fledging period again encompassed a 3-week interval (5-23 February), with peak fledging occurring on 13 February (vs. 19 February during 1991-92). The 6-day difference in peak activity of this breeding event was typical of the chronology of other breeding events this season, suggesting an earlier timing of breeding chronology. Compared to last season, 1992-93 was in general characterized by lighter than normal snowfall and pack ice.

12.5 Problems, Suggestions and Recommendations: This season was generally problem-free at Palmer Station. Minor problems with the telemetry equipment were again repaired on site, thus allowing this aspect of the research to achieve a potential comparable to last season. Although it is clear that some new Standard Methods can be added to the data being collected, predictable access to AMLR colonies due to weather and pack ice, which tend to limit small boat (Zodiac) operations, continues to be a problem. As a result, Standard Methods that depend on predictable and consistent access to study sites are not likely to be successfully implemented at Palmer. We are continuing to investigate ways of obtaining data relevant to CEMP within the constraints imposed on us by Palmer's unique working environment, and will report potentially new alternatives to NMFS as they are found.

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The entire scientific party is very grateful to Captain Frederick Jones and the officers and crew of the *Surveyor* for maintaining an atmosphere of cooperation and camaraderie throughout the cruise. Our success was due, in large measure, to their enthusiasm, professional competence, and attention to detail.

All departments contributed to our success. The electronic technicians helped to set up the CTD and underway data logging systems and kept the electrons flowing in the right direction; they helped the rest of us with our computers, printers, communications equipment, and just about anything that had a battery, wire, or silicon chip. The deck department helped us rig our nets, set up the acoustic tows, and ferry cargo. They also carefully deployed our equipment, lashed down our stray gear, and even spotted birds and whales that escaped our attention. The engineering department helped us fabricate a second towed body. The stewards adeptly handled our extra demands in an over-crowed wardroom. The survey department helped us sort plankton when we unexpectedly found ourselves shorthanded. They also worked tirelessly in conducting salinity calibrations. The officers provided a professional atmosphere and operated the ship in a safe manner.

Even more important was the cordial atmosphere aboard ship that was maintained throughout the cruise. The scientific party welcomed the friendship extended to them by the crew, many of whom offered welcome words of encouragement when times were difficult. Good shipboard atmosphere and communications contributed directly to our productivity.

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